THE DIET AND BEHAVIOUR OF HILL SHEEP.

by

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INTRODUCTION

The hill lands of Gt. Britain occupying one third of the agricultural acreage produce only about 4% of the total agricultural output. This same area however produces some 30% of the sheep and sheep products of the country. (Davidson & Wibberley, 1956)

The key therefore to the economic stability of agriculture in the hills is the hill sheep, for although an increasing number of cattle are being kept, it is difficult in many areas to overcome the problem of Winter keep.

The hill environment is considerably more adverse than that of the lowland and the hill ewe is required to survive the winter on an insufficient diet while satisfying the demands of the foetus at a most critical period of development. (Wallace, 1948) For these reasons the hill ewe has been the subject of various investigations based mainly on supplementation of the meagre winter diet.

The basic problem however is the interrelation between the sheep and its pasture. Ewes kept on virtually unrestricted hill grazings are able to exercise considerable choice both of the plant communities and species grazed. Under such conditions the factors that determine the distribution of the ewes over the hill are of considerable importance in determining the environment of the individual ewe. Social and flock behaviour is more evident under the low stocking rates encountered and the conditions may therefore be described as semi-natural. It is with this aspect of hill sheep production that the present thesis is mainly concerned.

THE SCOPE AND NATURE OF THE WORK.

The diversity of the hill sward, which provides the nutrient requirements of the sheep, imposes on them a diversity of nutritional levels and is therefore likely to be one of the most important environmental factors influencing productivity.

The plant communities which make up the hill sward differ in species, seasonal productivity and in nutritive value but the most important feature is the extent to which sheep graze them. Boulet (1939), Hunter (1954) and Hughes (1959) have all shown that various plant communities are grazed with a characteristic intensity depending on location, season and species composition and this must therefore have a profound effect on the nutritional level of the sheep. These workers however considered the grazing pattern of all the sheep on the area in question and the logical extension of this work is to determine whether each sheep grazing the 'heft' grazes and uses the area allocated to the whole flock or whether each ewe has an individual grazing territory or home range. This aspect of flock grazing behaviour has been investigated.

In conjunction with the above investigation, data have been collected on two other features of hill sheep behaviour viz the effect of shepherding on the distribution of the sheep and the distance travelled by them in their daily movements within the pasture.

The problem of the nutritional level of hill sheep and the availability of nutrients in the herbage consumed is one of the most important in hill sheep farming and one of the most difficult to investigate. Two approaches are possible, a study of the hill pasture itself by various cutting and sampling techniques, and more accurately, by the estimation of intake and digestibility using the grazing sheep in conjunction with housed animals. The latter approach using faecal index methods to determine digestibilities is the method most likely to succeed but is very difficult to adapt to hill conditions and in view of the lack of time and facilities could not be attempted by the writer. An attempt was however made to obtain some idea of the amount of dead grass consumed by the hill ewe in winter either deliberately to keep up dry matter intake or accidentally when grazing communities containing large amounts of dead grass.

Any variation in the grazing territory of individual families of sheep should provide a comparable variation in the nutritional status of these families, and an attempt was therefore made to investigate the extent of this variation by various methods of pasture sampling and analysis. Such methods of sampling can be criticised on the grounds that the sample obtained does not resemble the sample normally selected by the sheep. These criticisms are less important on hill pastures in winter however where the possibilities of selection is considerably less than on lowland swards. It is possible therefore to define the limits within which the diet can lie and in this way make a useful statement on its value. In conjunction with this, phenological data have been collected in order to determine the availability and possible digestibility of the hill herbage. This type of information, together with studies made of the individual grazing preferences and grazing method provides useful if somewhat uncritical data on the effect of hill pasture heterogeneity on the performance of the animals.

It is suggested that the hill sward and the grazing sheep, are intimately connected and cannot be considered separately. The basic heterogeneity and diversity of the sward imposes a similar diversity on sheep grazing behaviour and nutritional level which becomes critical in winter. These factors are closely connected with the breeding and management of hill sheep and for this reason are considered in this thesis.

The thesis is divided into four chapters each of which is self contained and has its own introduction and review of literature where appropriate. The general introduction commences on page 1 and general conclusions on page 142.

EXPERIMENTAL AREA

The data and observations contained in this thesis were collected at Sourhope, a hill farm managed by the Hill Farming Research Organisation. The farm which lies on the western slopes of the Cheviot hills in south-east Scotland consists of two farms, Sourhope itself and a small farm Auchope. Together these provide some 2,750 acres of hill rising from an altitude of 600 ft. to just under 2,000 ft. The hill vegetation consists mainly of grass dominated communities and is therefore known as a "white hill" (one possessing little heather). The sheep stock of the farm consists of two breeds, the Cheviot (both North and South country strains) and the Scottish Black face. The total sheep numbers of 1,450 ewes and 377 ewe hogs are carried at an overall stocking rate of 2.0 acres per ewe.

GEOLOGY AND TOPOGRAPHY

The greater part of the Cheviots consist of a basal platform of Silurian shales and grey wackes overlain by moderately acidic andesitic lavas. The higher hills are formed however from intrusive granite. Sourhope lies within the Andesite area but fairly close to the granite boundary on the north. The whole area was glaciated by ice from the west and consequently the topography is that of a typical glaciated region, namely, rounded hills with convex steep upper slopes.

The farm is divided into five main areas possessing natural boundaries each of which is known as a hirsel and is fenced. A hirsel would normally be shepherded by one man. Each hirsel is subdivided into one or more hefts as shown in Map 1, page 18.

A 'heft' is the term used for a group of sheep which habitually graze within the confines of a particular area of hill ground and which are normally self replenishing. It is also used to describe the area of ground itself. In order to prevent confusion the term will be used in this thesis for the area of hill ground and the group of sheep grazing it will be called the flock.

CLIMATE

The Table one comprising records for the nine years 1951 - 1960 summarises the main features of the climate at Sourhope.

Table 1. Annual rainfall (inches) and sunshine (hours) at Sourhope (1951-1960) inclusive.

Years	Rainfall (inches)	Sunshine (hours)
1951-52	34.7	1411
1952-53	44.3	1478
1953-54	39.9	1221
1954-55	26.9	1674
1955-56	37.0	1406
1956-57	32.8	1328
1957-58	33.7	1373
1958-59	21.0	1571
1959-60	47.7	1297
Average	35.2	1418

The records above run from November to October inclusive in order to fit in with the main livestock year. These records show that Sourhope is in a low rainfall area with high levels of sunshine. The early spring is consistently dry and sunny and the bulk of the precipitation falls in the winter months. Frosts of considerable severity also occur at this period.

More detailed data for the period August 1958 - September 1960, the period of study, are given in appendix 1.

MANAGEMENT

The basic management unit at Sourhope is the self replenishing group of ewes known as the "heft" (called the flock in this thesis).

Normally about 25% of the ewes are replaced by ewe hoggs bred on the heft in question each year, either because of death or culling (7%) or more commonly because they have reached 'casting' or drafting age (21-22%).

All sheep are kept continuously on the hill to which they are hefted and ewe hoggs are not wintered away. Both tupping and lambing take place on the appropriate heft and the ewe hoggs are normally prevented from breeding by a square of hessian covering the tail and vulva. Lambing normally occurs in April and May and the lambing percentage is approx. 85-95% depending on food supply, weather and the particular heft concerned.

Shepherding

Although the term shepherding includes all the many important tasks which must be done on the hill with the sheep, in the Borders a method believed to improve utilisation of the hill has been evolved, which is known as 'herding'. Traditional Border 'herding' is based on the idea that sheep require to be moved around the heft to utilise effectively the various communities. It demands that the shepherd or an assistant be on the hill twice per day and at certain times of the year more often. As it has been of so much importance in the past its objects are summarised in diagram 1.

Diag. 1

Traditional Border Herding.

Sheep moved uphill

1) Late afternoon
2) Autumn
3) Open weather in winter

Sheep moved downhill

1) Severe weather
2) Early morning
3) Lambing

Sheep moved onto poorer undergrazed areas

1) Summer
2) During the first months of pregnancy, when convenient.

Sheep moved onto better quality communities.

1) Before lambing
2) During lambing
3) During the early part of the lambs growth.
4) Just before tupping.

It is considered necessary to move the sheep uphill in the autumn and mild days in the winter in order to prevent over-grazing and soiling of the lower slopes to which the ewes may be confined for long periods during storm conditions. It is equally vital to prevent sheep being stormbound on the higher slopes during such conditions, to which end the sheep are moved down at the first sign of approaching storm.

Another important feature of Border "herding" is the attempt to utilise the hill to the full by concentrating the sheep on unpalatable areas of the hill, which would normally be under-grazed and in consequence rank and coarse. It is hoped to render these areas more palatable by this concentration of stock which removes excess growth. The ewes are moved on to this type of community when the nutritional needs of the ewes are lowest, i.e. between lambing and tupping and for the first few months of pregnancy. The more productive communities are reserved for the more critical periods such as the end of pregnancy, parturition and lamb rearing and lactation. At certain times of the year, it is considered necessary to exercise the ewe to prevent the accumulation of fat reserves, which are said to reduce conception, fertility and ease of lambing.

It will be seen that many factors must influence the shepherd in his "herding" policy and for this reason no hard and fast rules can apply. The shepherding policy of the heft concerned in the family grazing investigation will be described in more detail later and it will be seen that it departs from the procedure above. The present shepherding of the Gairs heft however is typical of that practised throughout a great deal of the Cheviot hills at the present time. Because of economic changes, few shepherds are willing to work the long hours involved with traditional "herding" and it has been necessary to modify it.

Very little information is available on the necessity or desirability of "herding" twice per day and no statement can be made as to the long or short term effects likely to occur with this reduction.

CHAPTER 1.

Part 1.

The investigation of home range behaviour in hill sheep, in particular the family relationship and its effect on home range.

Introduction.

Boulet (1939), Hunter (1954) and Hughes (1958) have all investigated by various methods the distribution of hill sheep grazing on unrestricted hill swards. They have also discussed the non-randomness of this distribution and its implications. More recently Hunter (1960) has given an indication of the existence of territorial or home range behaviour and in view of its importance to genetic and nutrition studies of sheep on free range grazing, it was decided to investigate this more fully.

It was considered possible that the territory of an individual may be 'passed on' to its offspring which will result in small family groups grazing different areas of the hill and consequently this was the main object of the observations. Data were also collected on the distances walked by individuals at various times of the year. In addition data were obtained on the effect of herding on the behaviour of individual ewes of different families.

REVIEW OF LITERATURE

The consideration of the sheep/hill pasture complex has been little studied, although the interrelation of these two is extremely important.

Boulet (1939) investigated many aspects of the grazing of a hill area in Wales. He showed that each plant community was grazed at a characteristic intensity and used the term Comparative Grazing Intensity (C.G.I.) to describe this intensity. The C.G.I. is defined as the number of grazing sheep per unit area of the sward.

Hunter (1954) used the concept of Comparative Grazing Intensity and investigated the seasonal variation in grazing intensity on the various plant communities on an area of hill in Southern Scotland.

Hughes & Davies (1958) have correlated the number of grazing animals per unit area on different sheep walks with climate, vegetation and soil type and have shown the greatest number of stock per unit area occur on Agrostis- Festuca grassland.

Attwood & Hunter (1957) have developed an instrument for quickly recording the position of a sheep on an area of hill. This instrument requires modification depending on the distance, slope and topography of the observed area. The instrument described in the above paper however was designed for the Gairs heft at Sourhope and is the instrument used for the observations in Chapter 1.

Hunter (1960) reports the possible existence of home range behaviour in hill sheep and gives information on six marked sheep none of which grazed the whole heft available to them. Each ewe restricted itself to about 150 acres of the 250 acres possible and the areas grazed did not coincide with each other nor with the general distribution of all sheep on the heft.

Although home range behaviour in sheep has not been reported in detail, several authors have referred to the relationship between sheep and deer also the social structure in wild feral members of the Artiodactyla.

Wormell (1960) has reported that 'competition' occurs between deer and sheep on the island of Rhum. The numbers of sheep have been drastically reduced and the red deer (Cervus elephus) have moved down on to the lower slopes. This could be a direct result of lower grazing intensity or possibly a reduction in the amount of disturbance due to reduced shepherding.

Fraser-Darling (1936) has shown that the red deer has a social organisation based on the existence of small family groups of hinds. These groups include yearlings, two year old and older hinds all probably descendants of the oldest hind which normally acts as the leader of the group. Each group of hinds belongs to a definite territory which is said to be 'somewhat' restricted and which overlaps to some extent the territory of other groups of hinds.

Palmer (1926) states that reindeer graze in large herds and show little individual territorial or home range behaviour.

Packhard (1946) & Spencer Clifford (1943) indicate a similar lack of territoriality in Bighorn sheep in the Rockies.

Feral goats occur in many parts of the country and although Watt (1937), Chapman (1889) & Russel Goddard (1955) have all studied them, little definite information is available on their home range or territoriality. They are said to occur on drier ground and graze in family parties of six or eight animals of both sexes.

Morton Boyd (1960) has studied the behaviour of Soay sheep on St. Kilda and considers that these primitive sheep show a distinct home range behaviour. The size of the home range is not known accurately but is believed to be influenced by the potential feeding value of the plant communities within it. The males normally form seperate parties except in the breeding season and the social structure is matriarchal.

Allee (1931) (1938) & Lorenz (1931) have shown that differences in aggressiveness has an effect on social organisation in mammals and birds. An individual learns by experience which of its companions are stronger and must be avoided and which are weaker. In this way a 'peck order' originates in which each animal 'knows its place'.

Burt (1943) & (1949) discusses the existence of both territorial and home range behaviour in mammals. It is stressed that the terms territory and home range are not synonymous and they are defined as follows. Home range is the area over which the animal normally travels in search of food whereas as territory is that part of the home range which is defended against intrusion by members of the same species.

In view of the fact that hill sheep have not been observed to defend the area of ground over which they graze, the term 'home range' has been used in this thesis.

Wallace (1948) has shown that the nutritional status of the ewe in late pregnancy has an important effect on the size and vigour of the lamb.

EXPERIMENTAL SITE

The heft chosen for this work was that studied by Hunter (1960) in connection with the investigation of the comparative grazing intensity on various communities, the present study being an extension of that work.

The Gairs was the heft chosen for this particular investigation as it is an easily observed hill with very little dead ground when viewed from the Fasset heft opposite, where the observation hut was situated (see Map 1, page 18). The heft is grazed only by Cheviot sheep.

Acreage & Altitude.

The Gairs covers an area of approximately 250 acres and is 950 yds. wide at its lowest point roughly tapering to 400 yds. at its highest and narrowest point some 1,500 yds. distant.

The lowest point of the heft is in the S.W. corner at about 850 ft. O.D. and the whole of the lower half of the heft is between this and 1,000 ft. O.D. with a gentle rise before the summit of the experimental area is reached at 1,750 ft. O.D. (see map 2, page 19).

Topography & Aspect.

The heft has a westerly aspect and therefore does not receive any sun until late in the morning. It is however sheltered to some extent from the east winds. North-easterly winds affect the sheep by driving them from North to South to seek shelter.

The heft is divided by the Rowantree Burn into two areas with somewhat different vegetation cover. These areas are known as the Gairs and the Dod Hill. These main features are shown on Map 2. Most of the sheep handling, marking etc. takes place at the sheep-folds marked and the field is normally used for lambing etc. and hay making. Sheep do not normally have free access to the field.

Vegetation.

The vegetation of the heft shows considerable diversity as do many hefts in this area and therefore must be considered in more detail. The Gairs and Dod having different vegetation are best considered separately.

Gairs.

This may be considered to be nutritionally inferior as by far the larger part of the area consists of a community in which the dominant species are Molinia caerulea, Nardus stricta, Juncus squarrosus and Calluna vulgaris. Molinia caerulea is deciduous and cannot contribute to the diet of the sheep during the critical winter period. High up on the Gairs there is a small patch of a Calluna vulgaris dominated community which may be a useful winter food. (Thomas (1934)). A similar type of community, in which the heather is associated with Juncus squarrosus and Molinia caerulea occurs on the eastern side of the Gairs and this again can be a useful winter source of food for the sheep. The community of least agricultural use on the heft occurs on this side of the burn and contributes little to the general productivity. This is the community in which Nardus stricta is the dominant species. The community occurs on the Dod Hill also, where for reasons explained later, it is considerably less grazed. Areas of very useful productivity occur to some extent on the Gairs, although they are much less important here than on the Dod.

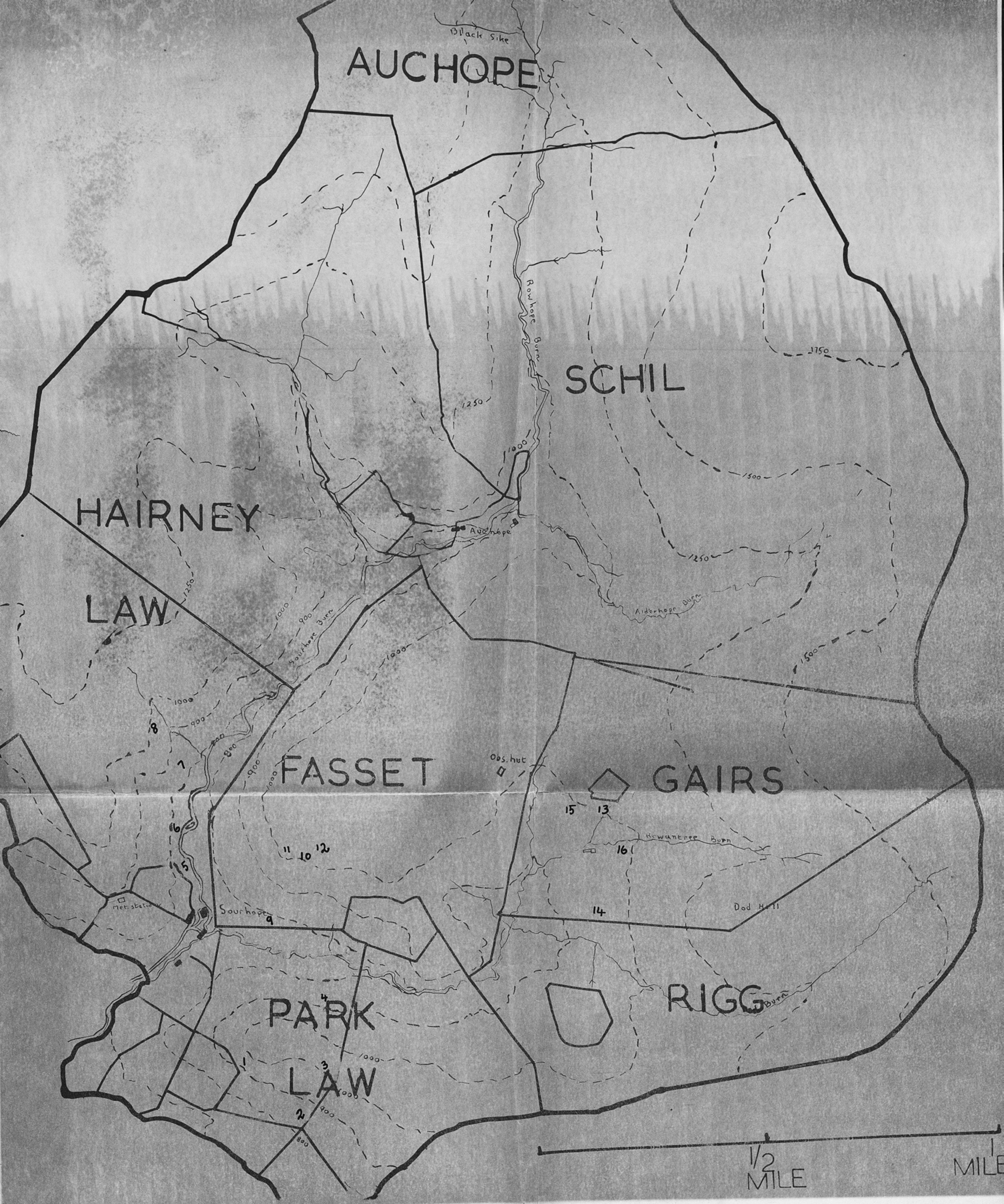
Dod Hill.

This includes all the lower and southern portion of the heft and is nutritionally superior. A great proportion of this half of the heft consists of the two most productive communities, those dominated by Agrostis tenuis-Festuca ovina (Agrostis-Festuca grassland) and those in which bracken (Pteridium aquilinum) has invaded Agrostis-Festuca grassland. The valley of the Rowantree burn which divides the Gairs and the Dod consists mainly of Pteridium aquilinum dominant communities, although in its upper half it has a rather complex vegetational pattern.

The chief vegetation types and their distribution are shown on Map 3, page 20 and their most important characteristics given in Table 2, page 21. Specimen species lists of the most important vegetational types are given in Appendix 2.

Map I

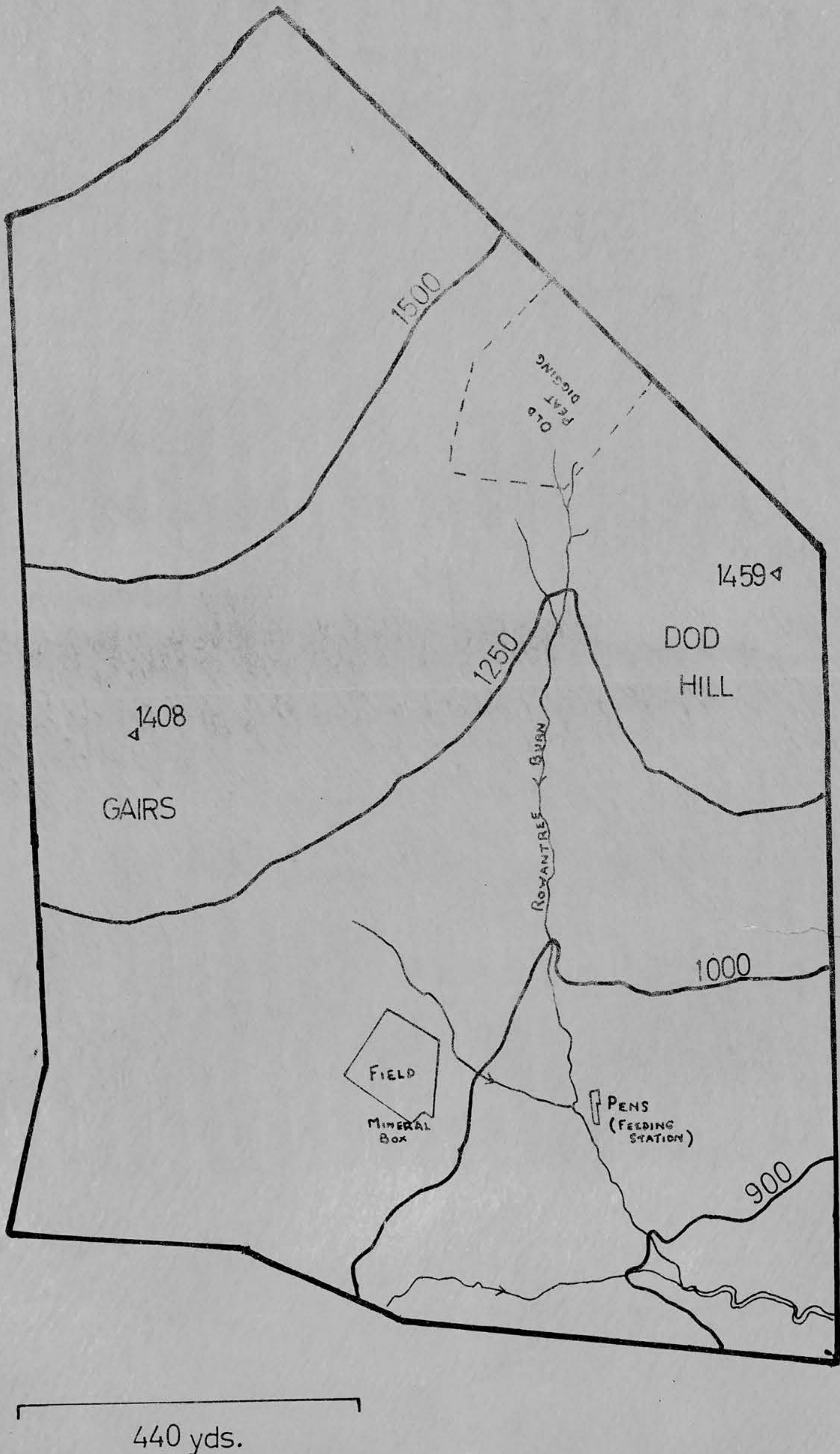
Experimental area, Sourhope and Auchope



AUCHOPE
Black Sike
SCHIL
Rowhope Burn
1750
1500
1250
1000
Auchope
Alderhope Burn
HAIRNEY
LAW
Sourhope Burn
900
800
FASSET
Obs. hut
GAIRS
Rowantree Burn
Met. station
Sourhope
Dod Hill
PARK
LAW
RIGG
1/2
MILE
1
MILE

Map 2

Topography of the Gairs heft


1500
OLD
PEAT
DIGGING
1459
DOD
HILL
1250
1408
GAIRS
ROXANTRES BURN
1000
FIELD
MINERAL
BOX
PENS
(FEEDING
STATION)
900
440 yds.

Map 3

Vegetation of the Gairs heft.

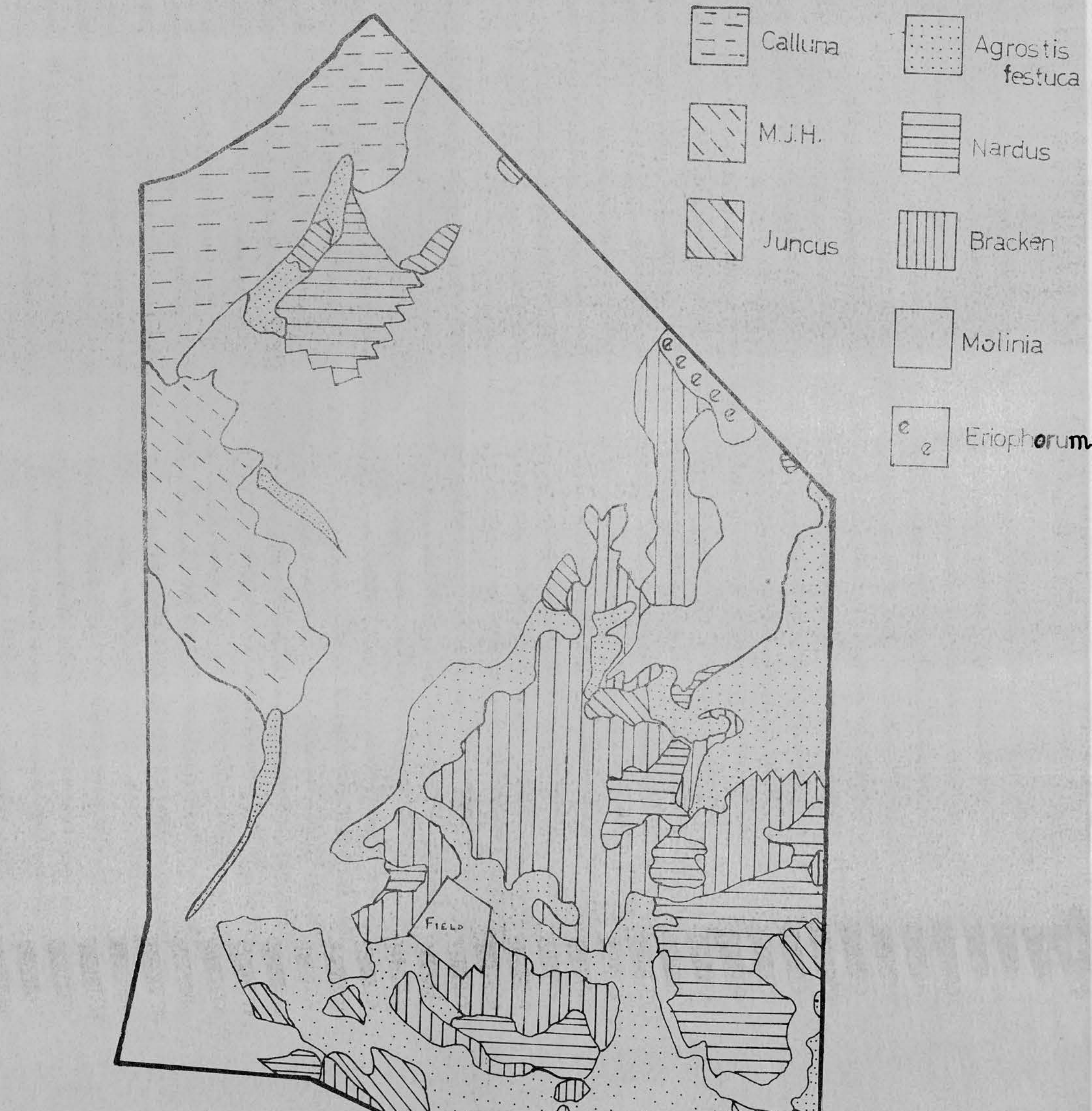

Calluna
Agrostis festuca
M.J.H.
Nardus
Juncus
Bracken
Molinia
Eriophorum
FIELD
440 yds.

TABLE 2

The main plant communities of the Gairs heft, their percentage area, main species and characteristics.

COMMUNITY	DOMINANTS	CO DOMINANTS	AREA (%).	COMMENTS
Agrostis-Festuca grassland.	Agrostis tenuis Festuca ovina.	Agrostis canina Festuca rubra Trifolium spp. Holcus mollis.	28.6	Most productive of the hill communities.
Pteridietum	Pteridium aquilinum.	Agrostis tenuis Festuca ovina Holcus mollis.	22.2	A light bracken cover is not necessarily inimical to high productivity.
Molinietum	Molinia caerulea.	Deschampsia flexuosa Festuca ovina.	36.1	Normally unproductive particularly during the critical winter period.
Nardetum	Nardus stricta.	Deschampsia flexuosa Festuca ovina.	7.1	An unproductive unpalatable species spreading to better quality communities.
Juncetum	Juncus effusus.	Agrostis canina Agrostis tenuis Festuca rubra.	0.3	Possibly useful during drought periods.
Eriophoretum	Eriophorum vaginatum.	Molinia caerula Erica sp.	0.7	Said to provide useful early grazing.
Callunetum	Calluna vulgaris	Erica sp. Festuca ovina Nardus stricta.	0.7	Useful at certain periods.
Molinia Juncus Heather community.	Molinia caerulea Juncus squarrosus Calluna vulgaris.	Festuca ovina Agrostis sp. Deschampsia flexuosa.	3.8	Characteristics intermediate between Callunetum and Molinietum.

SHEPHERDING

History

The recent history is relevant to this study as it is possible that it will have had some effect on the present distribution of animals over the heft.

In 1949 a completely new sheep stock, comprising all age groups in the correct proportions was introduced to the Southside hirsel within which the Gairs heft is located. The three hefts comprising the hirsel were not fenced and for this reason a certain amount of intermingling took place. For example the ground around the present Fasset/Gairs/Rigg boundary was common to all three hefts and the Gairs and Rigg heft extended further at this western end.

In 1951 the Fasset fence was erected in its present position and ewe numbers adjusted accordingly. This appeared to cause cobalt deficiency (pine) on the Rigg and Gairs and between 1953 and 1955 one third of the sheep stock were lost.

In October 1955 the fence between the Rigg and Gairs was erected along the centre of the Dod Hill. This was considered a natural dividing line and for this reason few sheep were caught on the 'wrong' side of the fence. The present Gairs heft is therefore the natural home range of the foundation stock of ewes placed there in 1949 and the pattern of distribution has developed since this.

Present shepherding policy

The basic pattern of herding has been described under management (p.7), with the limitations mentioned there. From personal observation and consultation with the shepherd concerned, the following time-table has been drawn up.

Table 3. Shepherding of the Gairs heft during the experimental period.

Month	Movement	Frequency of movements.	Comments.
November	Herded uphill in open weather	4 or 5 times a week	Herding not vital
December	Ewes bunched (tupping)	Daily	Herding important.
January	As November	4 or 5 times a week	Handfeeding.
February) March)	Weather influences herding	Once or twice/day	Handfeeding and approach of lambing.
April	Ewes brought down (near field)	Twice daily	Lambing, visits vital.
May) June)	Normal herding	3 or 4 times/week	Heft visited daily
July	Normal herding	3 or 4 times/week	Heft visited daily
August) September) October)	Normal herding	3 or 4 times/week	Frequent hand work with sheep involving gathering.

This is a record of the herding carried out by the shepherd during the year of study.

The sheep were weighed from time to time and gathered for this and other purposes. This took place regularly throughout the year and is unlikely to seriously affect the distribution of the sheep. To assist in recording the position of the ewes concerned, no herding took place on the day of recording unless it was necessary i.e. during lambing or tupping. On some occasions it was desired to observe the effect of disturbance and the sheep were therefore herded in the normal way and a record taken of the activity.

<u>The relationships of the observed sheep</u>.

By consulting the flock records kept at Sourhope since 1952 it was possible to select families of related ewes for the investigation. In order to reduce observation time, only families of three or more ewes were selected, although three families studied by <u>Hunter (1960)</u> were included which consisted of a pair of related ewes.

The families consist of a foundation ewe together with daughters and grand-daughters of these ewes. No information was available on the sires of the observed ewes and relationships are based therefore only on the female side, matrilinearly.

The families obtained, their year of birth and ear numbers are given in Table 4, page 25.

<u>Marking of the selected families and individuals</u>.

The sheep were marked with Bradford Sheep Marking fluid, which proved quite satisfactory and weatherproof, although no doubt any of the proprietary compounds woubd be equally efficient. The yellow 'bloom' dip commonly used for the treatment of show sheep was also employed and proved highly satisfactory. With suitable dilution this dye provided a range of colours from orange to yellow, of considerable permanence. Several of the Marking fluid colours

Table 4. Ear numbers, date of birth and relationship of ewes observed.

DAM	DAUGHTERS	GRAND-DAUGHTER
Family 'A'		
543 (born 1955)	896 (born 1958)	
Family 'B'		
548 (born 1955)	856 (born 1958)	
Family 'C'		
115 (born 1955)	845 (born 1958) 912 (born 1959)	
Family 'D'		
306 (born 1954)	573 (born 1956) 857 (born 1958)	
Family 'E'		
328 (born 1954)	568 (born 1956)	862 (born 1958) Died after 5 months.
	858 (born 1958)	
Family 'F'		
446 (born 1954)	588 (born 1956) 781 (born 1957) Died after 3 months.	
Family 'G'		
664 (born 1952)	585 (born 1956) 838 (born 1958)	863 (born 1958)
Family 'H'		
238 (born 1953)	897 (born 1956) 847 (born 1958)	
Family 'I'		
273 (born 1953) Died before commencement of observations.	777 (born 1957) 833 (born 1958)	

proved difficult to distinguish at the range involved (from 300 - 2,000 yds.) for example green blue and black. A method was finally adopted using only red and black marking fluid and the yellow dip. This precluded the use of a colour code for one family and a master sheet was used. Once this had been used several times no difficulty was experienced in quickly translating a particular marking to a ewe number.

Easily distinguishable letters such as T, O and W were painted on both of the animal's sides and on the rump. With a supplementary telescope of x30 magnification it proved possible to distinguish these letters on most occasions, although in bright sunlight and early mist in the morning, reading the letters was impossible. Identification was difficult with reclining sheep although in most cases if an animal was kept under observation it generally moved sufficiently for identification to be made.

Observation of the marked individuals.

The recording of the position of marked individuals and of the position of all the sheep within the heft, was carried out on one day per week throughout the experimental period. (9th September 1959 - 16th August 1960). Each day's observations ran from dawn to dusk at two hourly intervals for the first ten weeks, changing to hourly intervals later. Observations were made, whether the sheep were grazing or not. The observations were made using the instrument devised by Attwood & Hunter (1957) and the methods and grids were those described by them.

The sheep locations were transferred from the paper sheets used on the machine to a master sheet using a transparent sheet gridded in rectangles representing 100 x 200 ft. on the ground. The totals of four such grids representing 400 x 200 ft. were added together in order to simplify extraction of the data.

RESULTS

The results for the ten families are given in Diagrams number 2-10 commencing on page 28, each dot representing one ewe location.

The distribution of the entire flock of sheep on the heft is shown in Diagram No. 11, page 37, and a simplified vegetation map obtained by recording the main vegetation type in each 400 x 200 ft. rectangle is given in Diagram No. 12, page 37.

Diagram 2

Ewe distribution over the Gairs heft

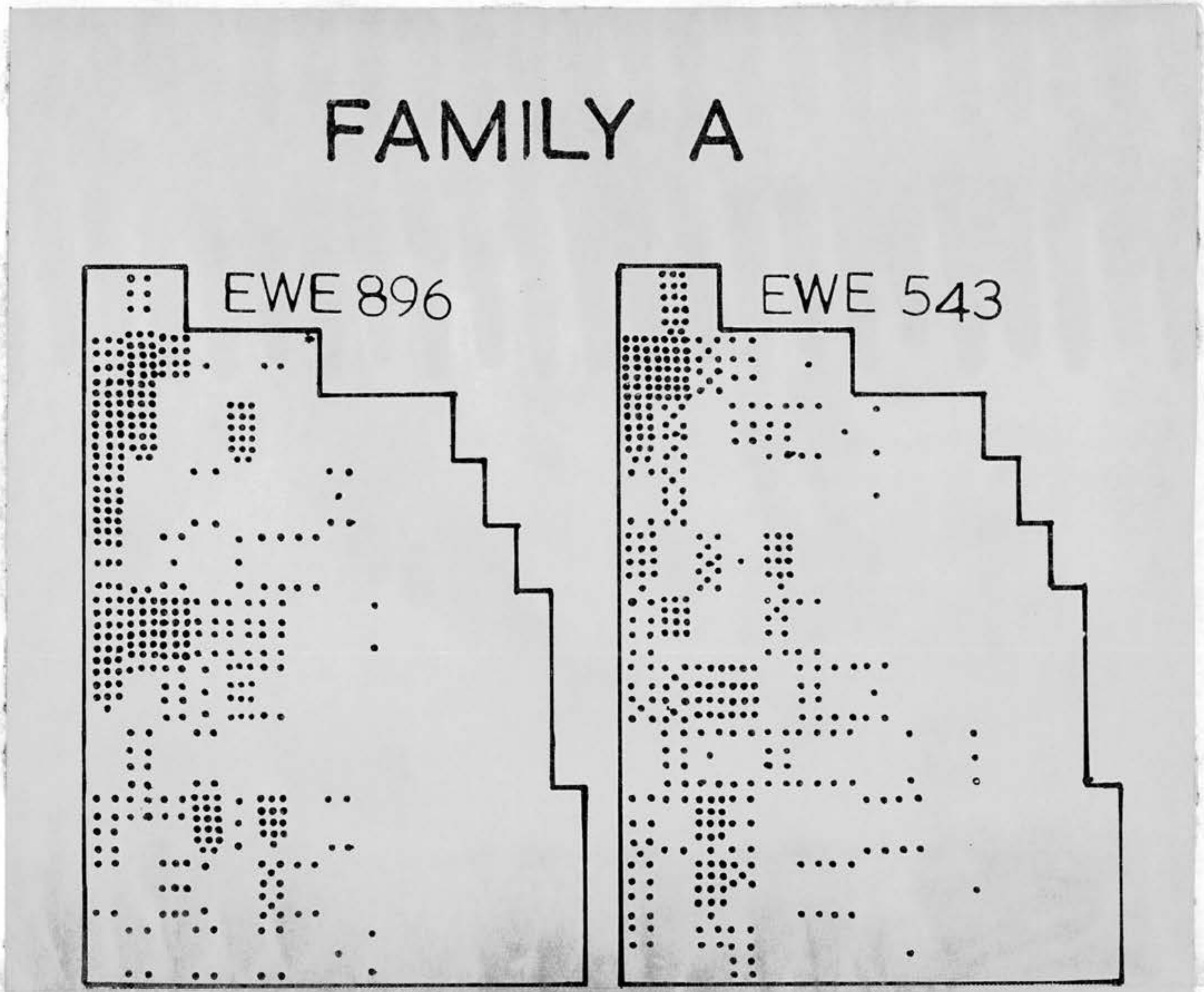


Diagram 3

Ewe distribution over the Gairs heft

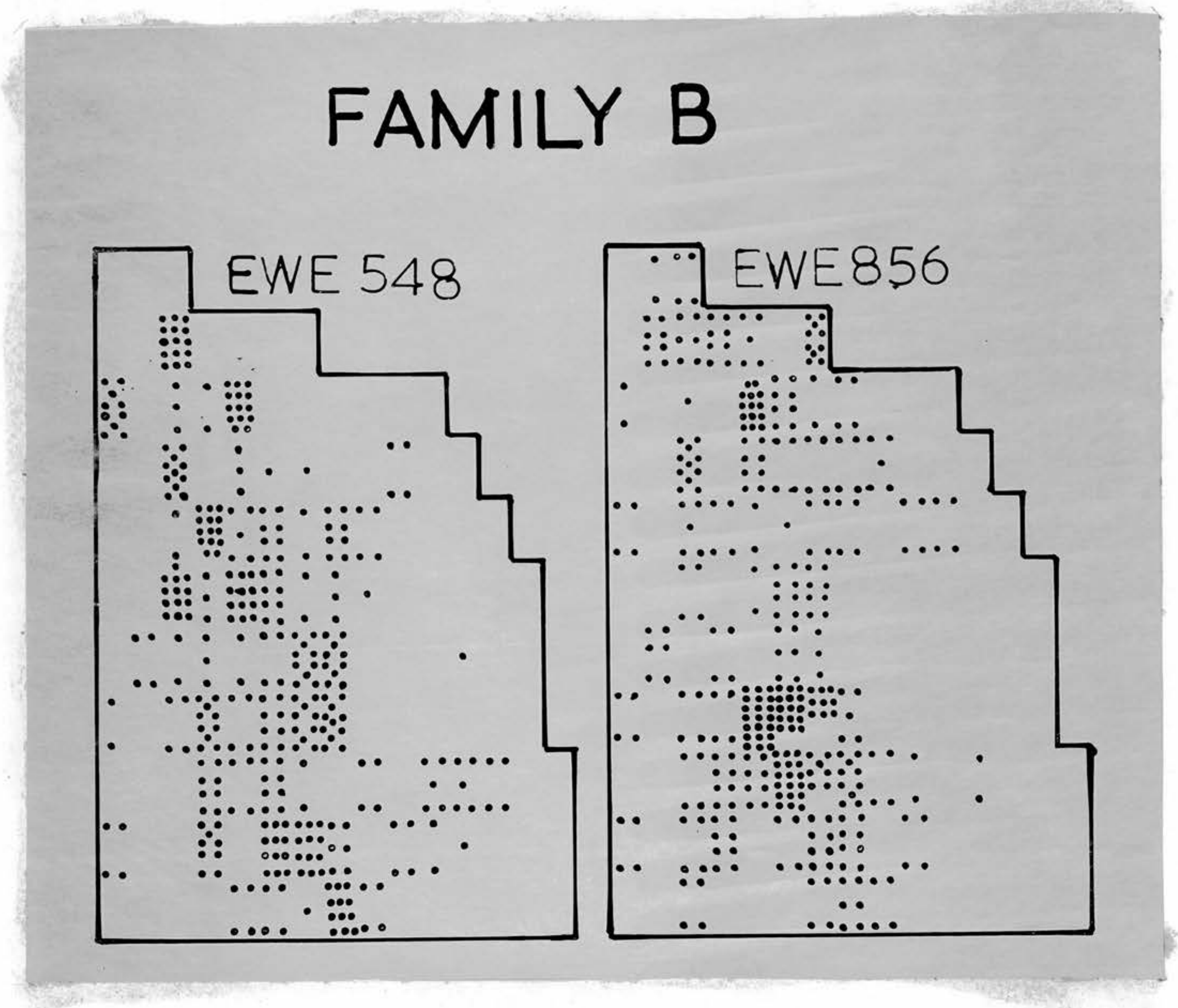


Diagram 4

Ewe distribution over the Gairs heft

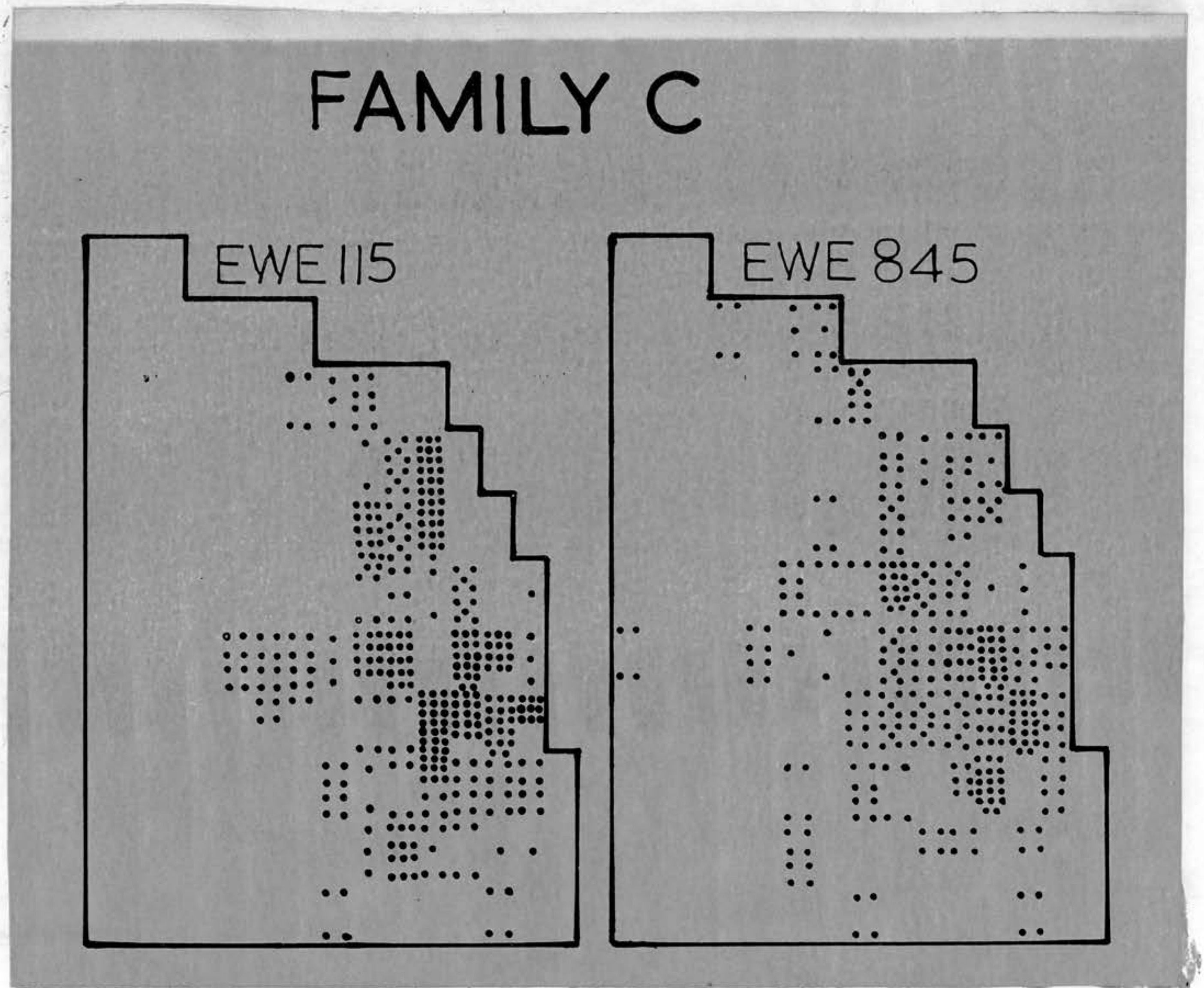


Diagram 5

Ewe distribution over the Gairs heft

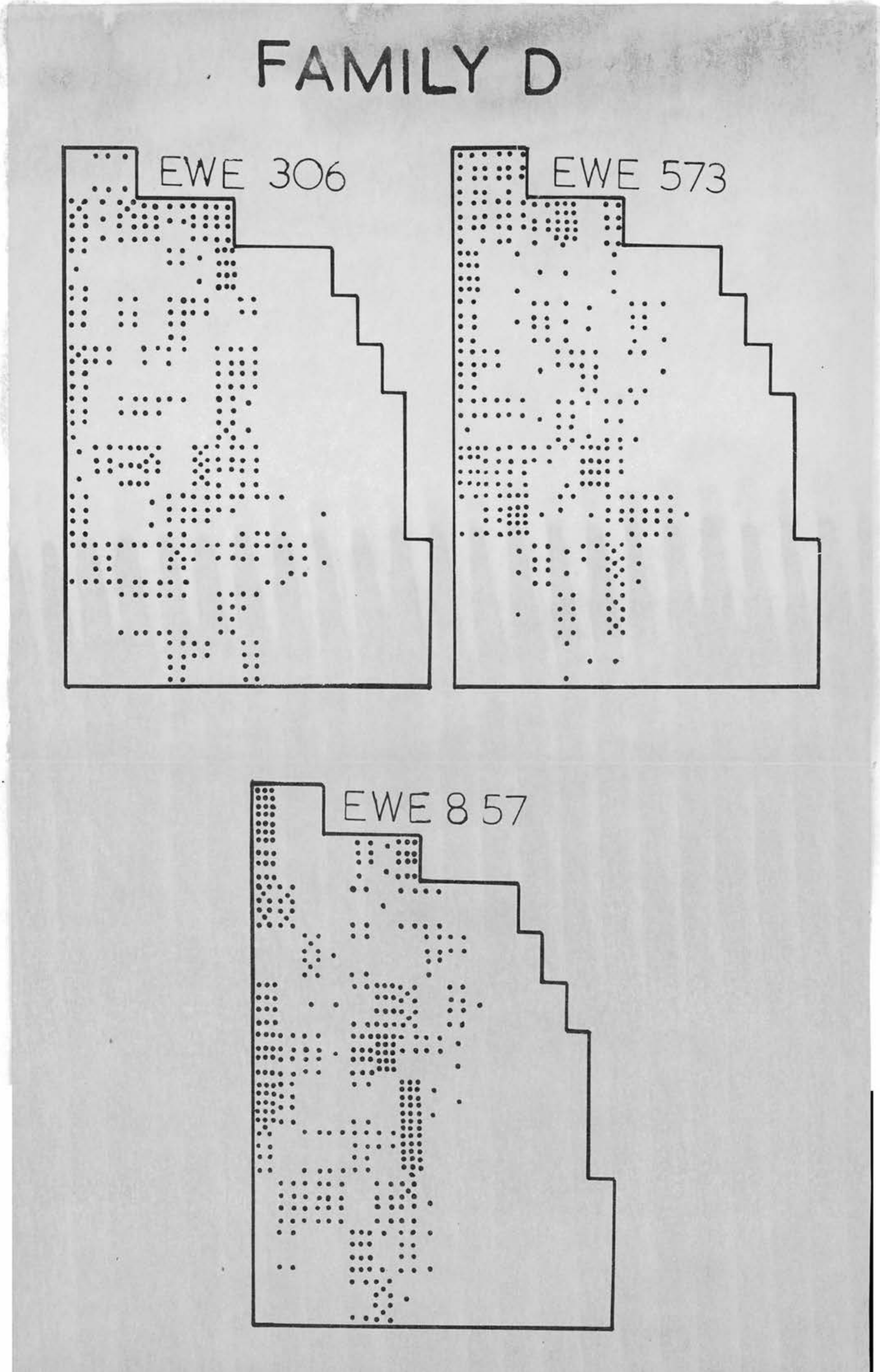


Diagram 6

Ewe distribution over the Gairs heft.

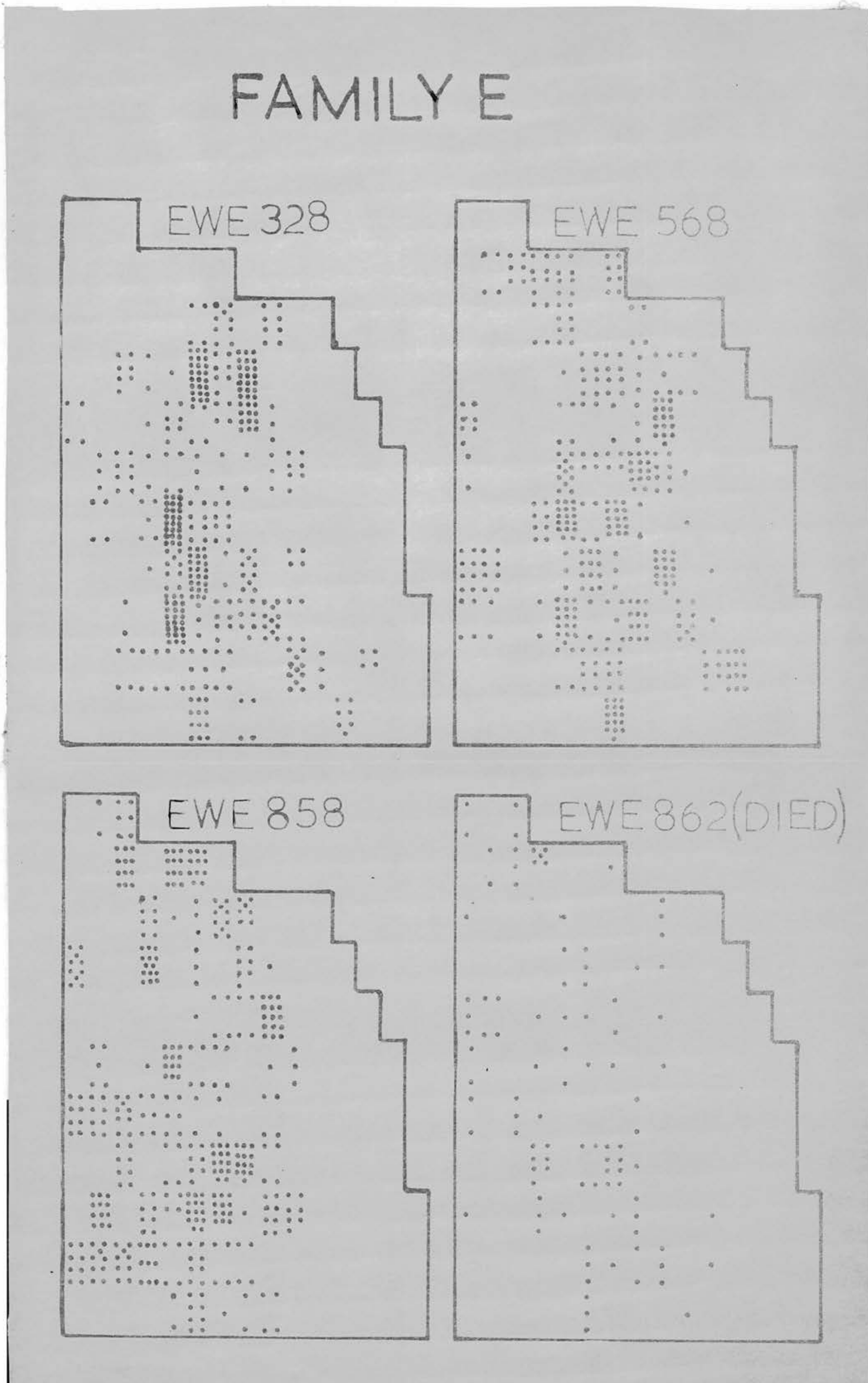


Diagram 7

Ewe distribution over the Gairs heft

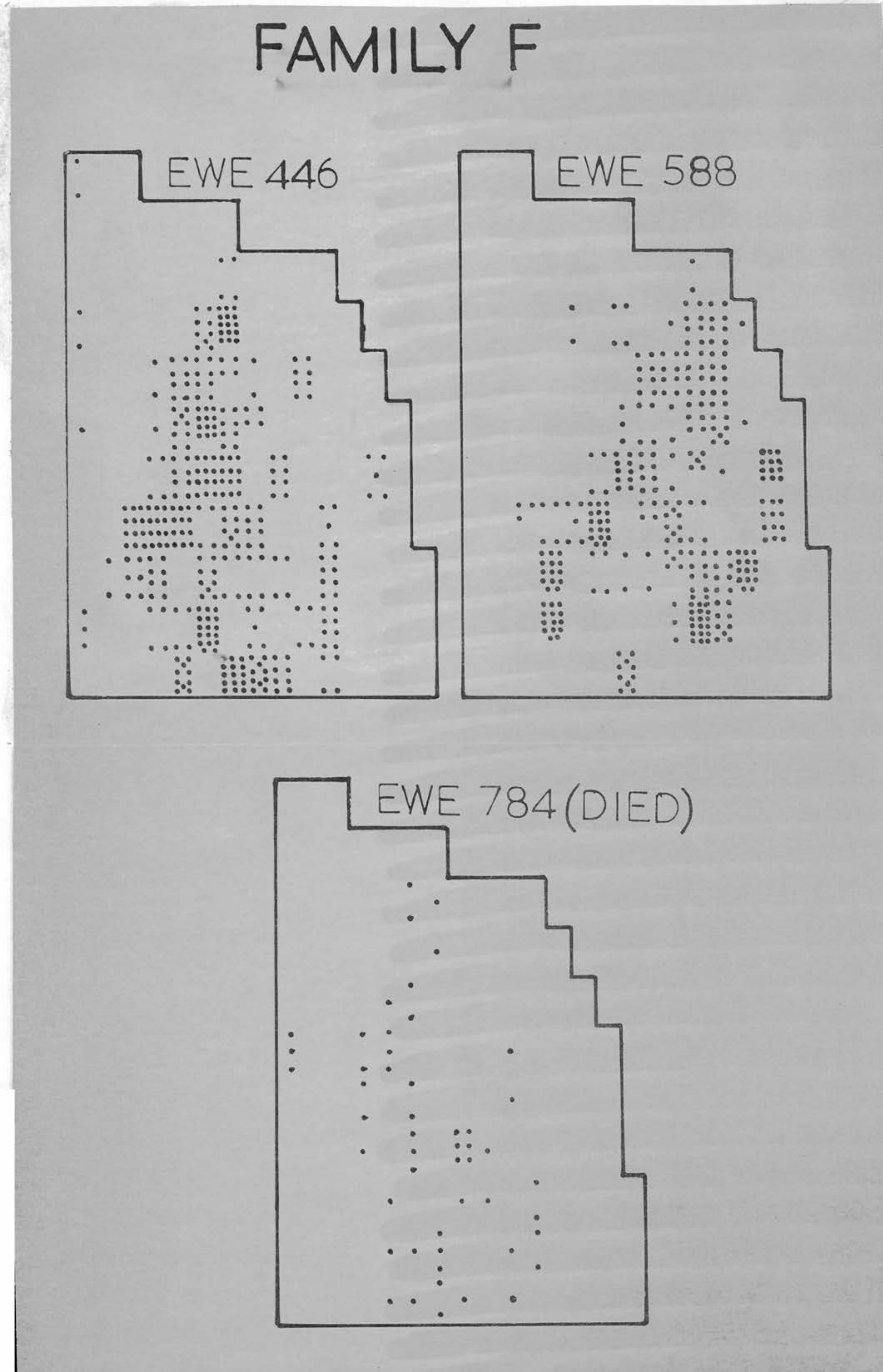


Diagram 8

Ewe distribution over the Gairs heft

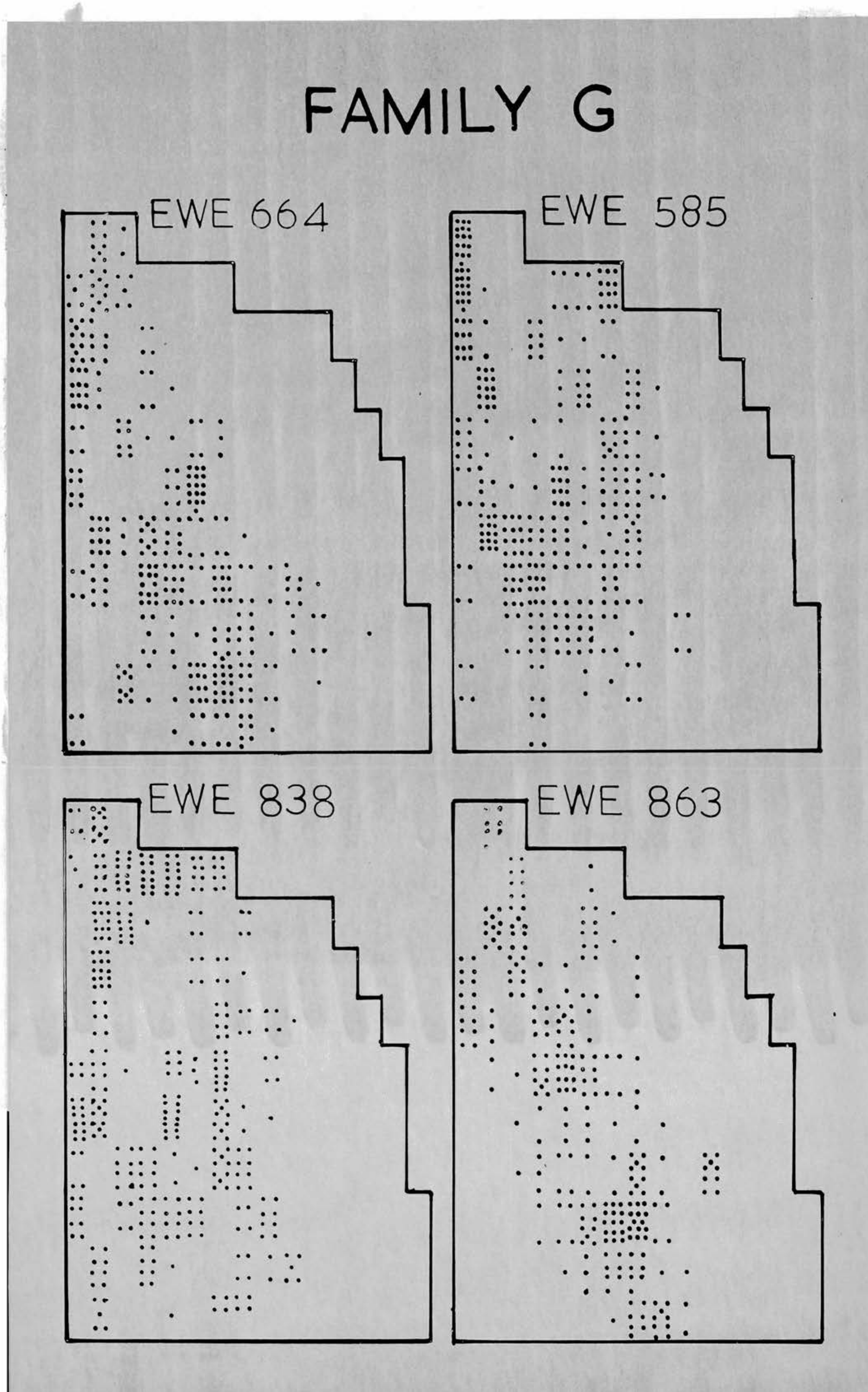


Diagram 9

Ewe distribution over the Gairs heft

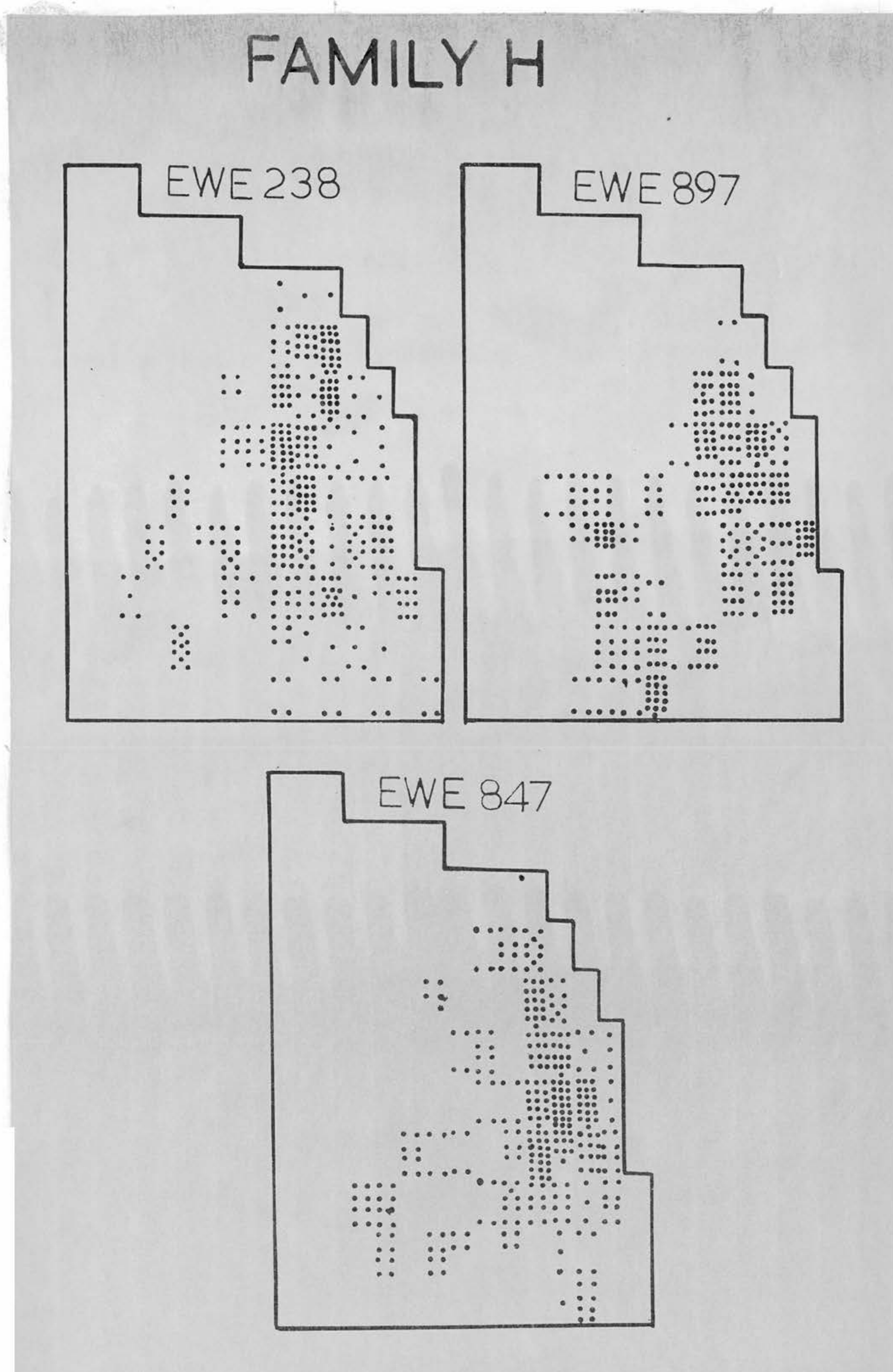


Diagram 10

Ewe distribution over the Gairs heft

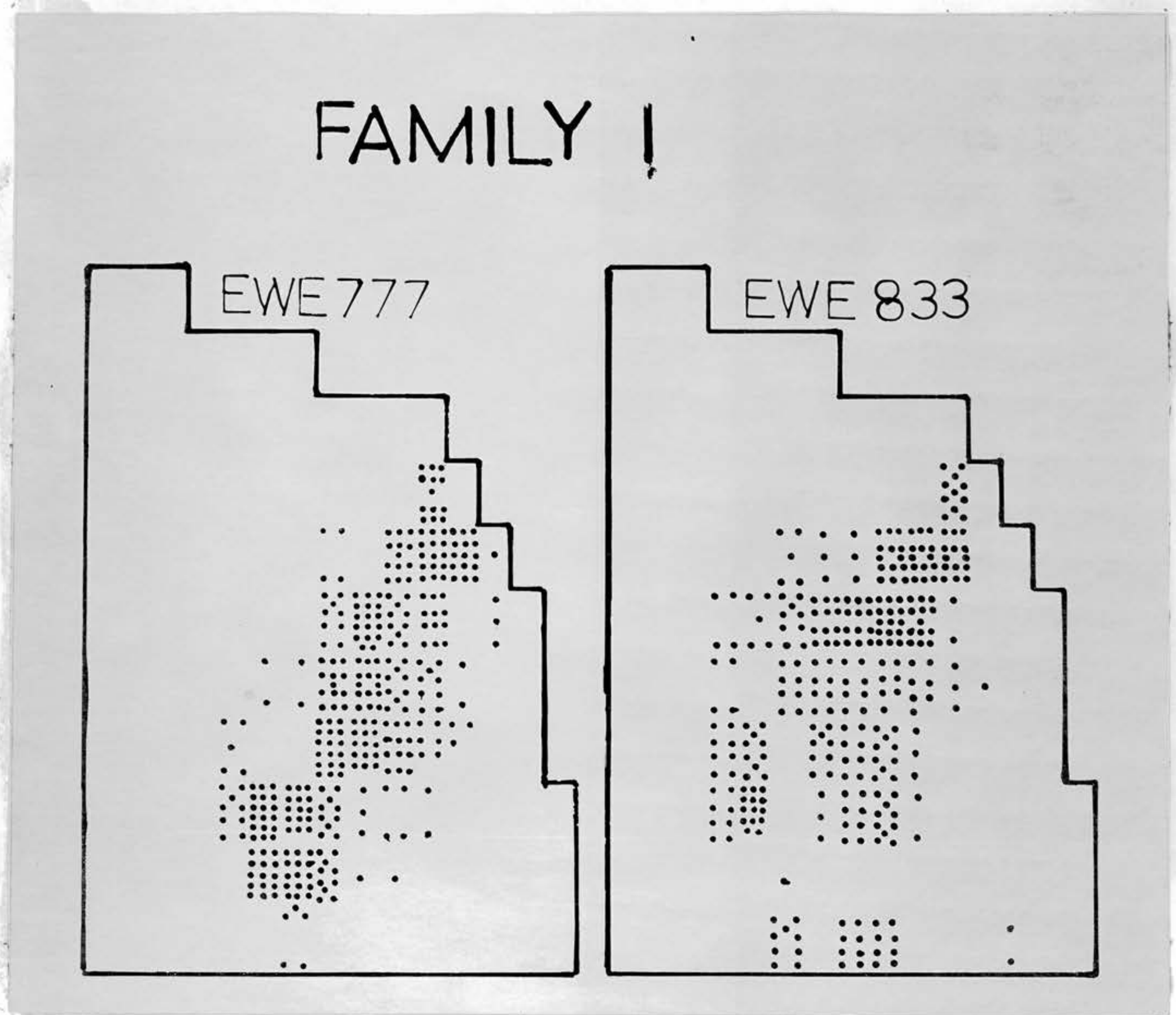


Diagram II

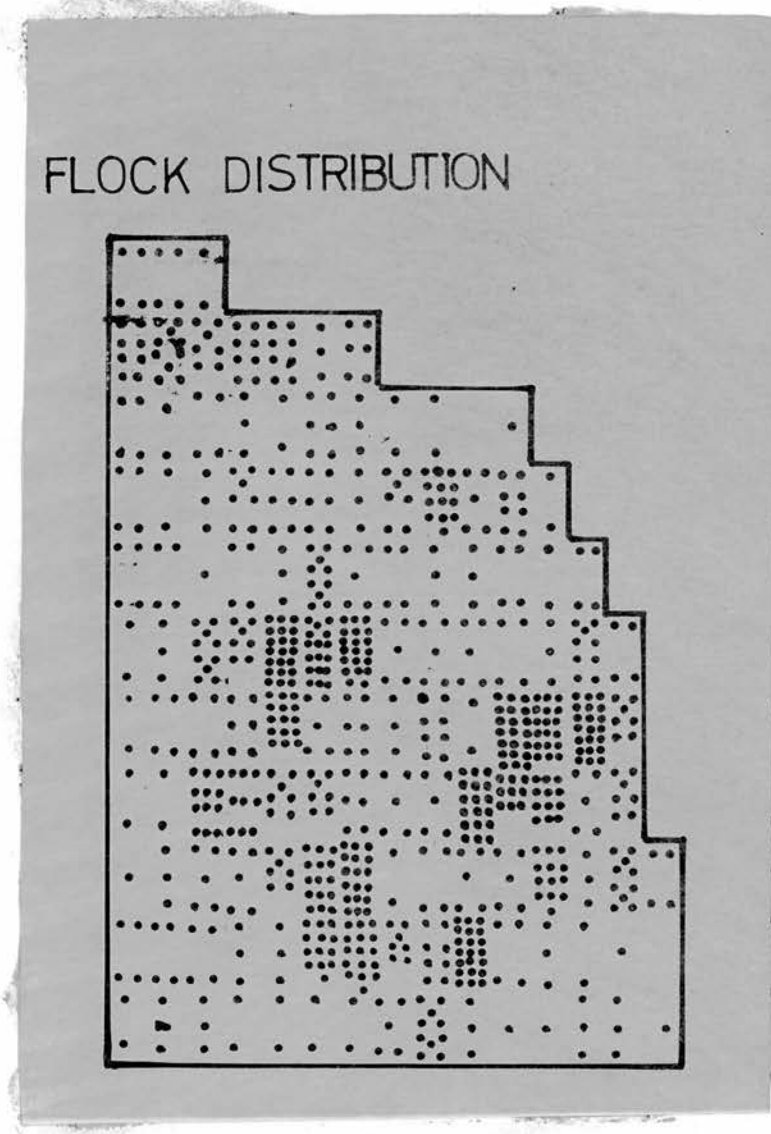
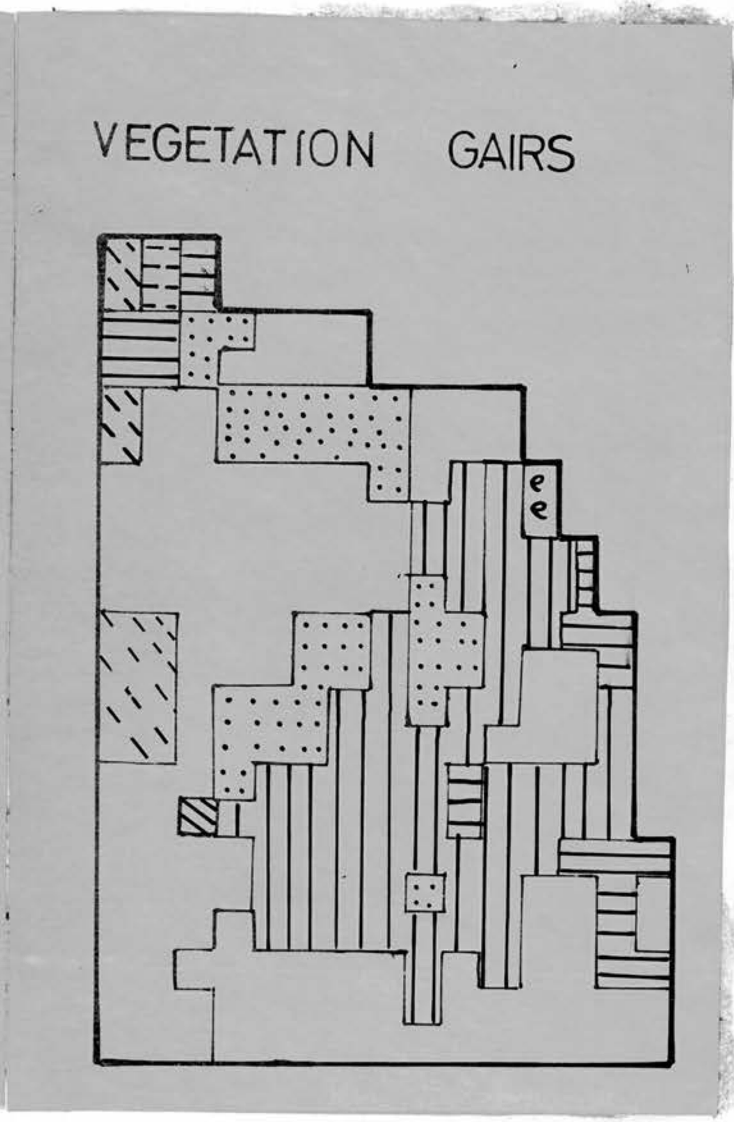


Diagram I2



Each dot represents I00 ewe-
observations, where less than
I00 the square is left blank.

Family 'A'

Ewe No. 543 occurs in 53 squares and No. 896 in 48 squares. This comprises 39.8% and 36.1% of the total area available for grazing or resting. These two ewes possess to a marked degree a similar home range with a concentration of occurrences in the same area of that range.

Family 'B'

The home range of this family is somewhat larger, consisting in the case of ewe No. 548 of 45.9% of the total available area and in the case of No. 856, 47.4% of the total available area. It is a good deal more central than that of family 'A' with no area of greater density, however ewe No. 856 does have a region of preference centred around the field, with its Pteridium aquilinum and Agrostis-Festuca communities. The territories are coincident although less so than family 'A'.

Family 'C'

This family has a high degree of aggregation in a rather restricted range. They offer a contrast to family 'A' as the home range is on the Dod hill with a few occurrences on the Gairs. Ewe No. 115 occurs in 35.4% of the available area while No. 845 occupies 37.6%.

Family 'D'

Although resembling family 'A' this group of three ewes has a rather less restricted range, 306 occuring in 48% of the available area, 573 in 49% and 857 in 44.3% of the area. Once again a fair degree of similarity occurs in their home ranges which are based mainly on the Gairs (as 'A') but with a tendency for the focus to be nearer the Rowantree Burn.

Family 'E'

The distribution of the four ewes comprising this family are shown. Unfortunately ewe No. 862 died 5 months after the investigation began. The common home ranges of the three ewes 328, 568 and 858 are more central than any of the families so far examined. They are not as restricted as certain of the others, as ewe No. 328 occupies 41.5% and ewes 568 and 858 occupy 46% of the available area.

Family 'F'

This family of three ewes was reduced to two by the death of No. 781 within three months. This family is interesting for the obvious differences between the home ranges of No. 588 and 446. Although somewhat restricted (588 occurring in 44% of the area and 446 in 37.6%) there is a lack of similarity in their distribution apart from some degree of overlap in the region of the field. This overlapping at the field can be explained by the presence there of a mineral box which attracts the ewes. No suitable explanation for the dissimilarity can be given. Ewe No. 781 appeared to be developing the home range of her dam (446) but her death made checking this impossible.

Family 'G'

This family's home range is the Gairs and the lower central area of the heft. Ewe 664 has a restricted home range of 46% of the area available and No. 863 has an even more restricted home range of 42% of the area available, whereas Nos. 838 and 585 have a range of 46% and 45% respectively. Nos. 838 and 585 occupy coincident areas at the top of the Gairs and the central area of the heft. Nos. 664 and 863 have a slightly lower and more central home range although still basically similar.

Family 'H'

This family has one of the more restricted ranges, No. 238 having occurrences in 39% of the available area and 847, 31.6%. No. 897 occurs in 28.9% of the available area. This family is restricted to the Dod Hill with some occurrences in the region of the mineral box.

Family 'I'

The home ranges given are those of the daughters of a foundation ewe which died some time previously. They were very restricted (No. 833 occurring in 31% and No. 777 in 26.3%) with much common ground. The range is a central one reaching across the heft from the top of the Dod to the lower central position of the Gairs.

CONCLUSIONS

The twenty-five ewes observed all exhibited home range behaviour. Although each one had access to every part of the heft, they were observed only on a portion of it. The average home range was 40.2% of the heft which represents approximately 100 of the 250 acres available but the greater part of their resting and grazing occurred on less than this. The figure of 100 acres agrees with the acreage quoted by Hunter (1960) in a preliminary study of this phenomenon. The smallest home range was that of ewe No. 777 which occurred on only 26.3% of the total possible grid squares and therefore had a possible grazing area of 65 acres. The least restricted home range was that of ewe 573 with a possible acreage of 121 or 49% of the total. None of the ranges were identical but could be resolved into three main types.

1) The whole of the Gairs i.e. on the E of the burn.
2) The central portion of the heft, mainly on the banks of the Rowantree burn and including both the Dod and the Gairs in the lower portion.
3) The whole of the Dod hill i.e. on the W of the burn.

One pair of ewes (Family 'I') have a unique home range, including the upper portion of the Dod and the lower portion of the Gairs.

Although the home range of each ewe was unique, a strong family similarity can be observed. Members of the same family occur in the same areas and possess home ranges closely resembling the other members of the family. The home range of the family does not resemble that of the whole flock and the distribution of the flock is a result of the superimposition of members of different family groups each possessing different home ranges. The mechanism by which home range behaviour has developed will be discussed later, but it is of interest to note that the family home range relationship is very difficult to break down. Herding and feeding have been studied in this connection (page 52) but a more striking example of the permanence of the habit is provided by ewe No. 664. During the autumn/winter period of 1958/59 this ewe was removed from the heft for experimental reasons and was housed on slatted floors for several months. When returned to the heft she returned to the same home range as her offspring.

Climate appeared to have little effect on the family pattern although on certain occasions N.E. winds did drive the entire flock of ewes towards the S.W. to seek shelter in the valley of the Rowantree burn.

CHAPTER 1

Part 2.

The Home range and its effect on the plant communities grazed.

Introduction

Because of the diversity of the swards on the Gairs the different home ranges include different plant communities and individual preferences by the various families for a particular community may be responsible to some extent for the distribution of the families over the heft. For this reason and the fact that gross differences between the productivity of the various plant communities both qualitatively and quantitatively may be reflected in the performance of individual ewes and families of ewes, details of the distribution of the families in relation to the vegetation was considered. Table 5, page 45, gives details of the number of occurrences on the various communities of the heft. Table 6, page 46, shows the occurrences per unit area of the particular community for each ewe, which gives a measure of the ewe's relative preferences for the various communities. The term 'occurrence index' is used for this figure which is similar to the 'comparative grazing intensity' used by Boulet (1939). The occurrence index (O.I.) is calculated as below.

$$\text{Occurrence index} = \frac{\%\ \text{occurrences of ewe on community}}{\%\ \text{area of community}} \times 100$$

The tables show that family home range affects the intensity with which individual communities are grazed by the family. Although differences within the family occur, in general they are slight and this pattern of family grazing is in most cases different from that of the flock as a whole. The families as a whole exhibited seasonal preferences for certain communities (as noted by Hunter (1954)).

Results (see page 45).

Table 5 Occurrences of the study ewes on the various communities of the Gairs heft

Ewe No.	Mol.	M.J.H.	Ns.	A/F	Pt.	Junc.	Call.	Er.	Total
Family 'A'									
896	103	14	36	81	28	-	6	-	278
543	110	58	46	85	44	2	17	-	362
Family 'B'									
548	103	14	-	121	100	2	-	-	340
865	97	8	12	107	116	2	2	-	344
Family 'C'									
115	51	-	13	104	172	-	-	-	330
845	50	4	8	132	143	-	-	5	342
Family 'D'									
306	112	20	14	76	76	-	4	-	302
573	114	41	24	58	63	9	7	-	309
857	164	54	12	75	92	2	-	-	399
Family 'E'									
328	126	7	4	123	106	-	-	-	366
568	82	2	4	116	121	-	-	-	327
858	112	21	6	123	96	4	2	-	362
862	36	5	4	15	31	-	-	-	91
Family 'F'									
446	90	1	-	125	127	6	-	-	349
588	57	-	-	78	151	1	-	-	288
784	10	3	-	12	17	-	-	-	42
Family 'G'									
664	84	30	17	94	92	-	9	-	326
585	158	37	17	70	73	6	-	-	361
838	155	34	11	70	67	4	10	-	351
863	99	2	-	65	96	-	7	-	269
Family 'H'									
238	56	-	25	110	153	-	-	-	344
897	40	-	9	132	165	-	-	-	346
847	73	-	10	101	128	-	-	-	312
Family 'I'									
777	64	-	13	69	166	-	-	-	312
833	47	-	3	104	128	-	-	-	282

Key

Mol.	Molinietum
M.J.H.	Molinia, Juncus, Heather community
Ns.	Nardetum
A/F	Agrostis-Festuca grassland
Pt.	Pteridietum
Junc.	Juncetum
Call.	Callunetum
Er.	Eriophoretum

Table 6 Occurrences of the study ewes per unit of the community. (Occurrence Index)

	Mol.	M.J.H.	Ns.	A/F	Pt.	Junc.	Call.	Er.
% of total area.	36.1	3.8	7.1	28.6	22.2	0.3	0.7	0.7
Ewe No.								
'A'								
896	85	640	151	84	37	-	285	-
543	84	420	225	80	54	166	715	-
'B'								
548	84	110	-	126	128	200	-	-
856	81	60	49	109	152	200	85	-
'C'								
115	42.6	-	55	110	234	-	-	-
845	39.5	Occ.	32	135	188	-	-	215
'D'								
306	101	170	65	91	113	-	186	-
573	101	350	110	66	92	954	330	-
857	114	360	42	66	104	166	-	-
'E'								
328	96	50	15	118	130	-	-	-
568	69	20	17	124	166	-	-	-
858	86	150	22	119	119	367	71	-
862	109	140	62	58	153	-	-	-
'F'								
446	72	8	-	128	164	553	-	-
588	55	-	-	95	234	133	-	57
784	66	19	-	100	182	-	-	-
'G'								
664	71	240	73	101	127	-	394	-
585	120	270	66	66	91	554	-	-
838	121	250	43	70	86	367	400	-
863	102	18	-	86	160	-	371	-
'H'								
238	45	-	101	155	200	-	-	-
897	32	-	36	166	215	-	-	-
847	65	-	45	144	185	-	-	-
'I'								
777	57	-	59	186	240	-	-	-
833	47	-	14	159	204	-	-	-

Key

Mol.	Molinietum
M.J.H.	Molinia, Juncus, Heather community
Ns.	Nardetum
A/F	Agrostis-Festuca grassland
Pt.	Pteridietum
Junc.	Juncetum
Call.	Callunetum
Er.	Eriophoretum

NOTE:

An occurrence index of 100 indicates that the community in question is occupied at a level that would be expected if the sheep were distributed uniformly over the hill. Figures above or below 100 show that the community is being utilised more or less than would be expected under uniform grazing conditions.

Molinietum

This community normally has an "occurrence index" (O.I.) of under 100, although it may rise above this at certain times of the year. Only families 'D' and 'G' have an O.I. over 100, all the others being below as expected (e.g. 'H' and 'I'). The communities dominated by Molinia caerulea are, therefore, little utilised except by these families.

Molinia-Juncus-Heather community.

This community is closely related to the previous one and the general pattern of utilisation is the same. Juncus squarrosus and Calluna vulgaris are grazed at a time when little else is available during the winter. Families 'I' and 'H' were never observed on this community which occurs in their territories. Family 'F' and 'C' had a very low occurrence per unit area on this sward although both families did graze the Gairs slightly.

Families 'A' and 'D' had a very high occurrence on this community (with one member of family 'A' having an occurrence index of 640). This ewe's territory was the whole of the Gairs, more particularly the top portion and the main reason for her occurrence outside this area was herding or visits to the mineral box.

Nardetum

Nardus stricta, the dominant grass in this community, is a winter green, early species, of low palatability and it normally has a low O.I. The associated species do however provide a palatable growth, with a consequent high grazing intensity at certain times of the year. Of the families studied only one, 'A', had an above average occurrence index on this community. The Dod which possess 68% of the Nardus area is grazed by three families ('C', 'H' and 'I') which graze it at a low intensity but 'A' and 'D' which are associated almost exclusively with the Gairs give a high O.I. (in the case of 'A' above 100) for the community. This difference can be explained by considering the adjacent communities. In the case of the Dod the Nardus stricta areas are completely surrounded by Agrostis-Festuca communities and Pteridium aquilinum dominant communities, whereas on the Gairs (32% of the Nardus stricta area) the area is mainly surrounded by Molinia caerulea and Calluna vulgaris dominant communities. Presumably the Agrostis-Festuca on the Dod provides sufficient palatable grass to prevent the grazing of low palatability Nardus stricta, whereas on the Gairs little else of a high productivity or palatability occurs.

Agrostis-Festuca grassland.

This is the most valuable of the hill grassland and this is reflected in the high O.I. Seven of the nine families in this investigation have a higher than average occurrence per unit area, the two exceptions being families 'A' and 'D'. These two families might be expected to have a high number of occurrences as approximately 50% of the Agrostis-Festuca occurs within their home ranges.

Pteridietum

Only Family 'A' gives a below average O.I. on this sward type, which does occur within the limits of its territory. Bracken dominant communities appeared to be grazed quite as intensively as Agrostis-Festuca by the other families concerned and provide a considerable source of high quality grass early in the season, when grasses under the bracken are accessible and have been protected to some extent by the covering layer of bracken.

Juncetum

This area is a small one and for this reason the very high O.I. given by several of the ewes on this community is probably unrealistic. However it is possible that in the normally dry spring encountered at Sourhope such permanently damp flush areas provide valuable grazing.

Callunetum

This area is a small one, but may provide useful keep during the winter season particularly as heather of medium age is present. The two families occupying the upper portion of the Gairs, 'A' and 'D' again graze this community at above average intensity. This is to be expected as the community lies wholly within their territory.

Eriophoretum

The small patch of this community lying high on the Dod is grazed at a very low intensity, only two ewes occurring on it. One of these, No. 845, gave an O.I. of 215 and is the only animal occurring at above average intensity on the community. Several families include the Eriophoretum within the limits of their territory e.g. 'C', 'H' and 'I' and yet none of the ewes comprising these families (except ewe 845, family 'C') occur on this community.

CONCLUSIONS

The fact that sheep are distributed in a non-random fashion over the hill in family home ranges suggest that a similar non-randomness occurs in plant communities grazed. This does happen and has been demonstrated in the previous pages. Individual differences between sheep in the same family occur but in general the communities grazed by individual ewes are very similar to those grazed by other family members. The communities grazed by a family are not necessarily those grazed by other families or by the entire flock.

The occurrence index (table 6, page 46) shows that the majority of the families occur most frequently on the Agrostis-Festuca and Pteridium aquilinum dominant communities (Pteridietum) and in view of the higher production and palatability of the grasses in these communities it is not an unexpected finding. These two communities provide the bulk of the grazing of the flock and therefore in showing a 'preference' for them the individual families are exhibiting the 'preferences' of the flock.

Not all the families have the highest grazing intensities on the Agrostis Festuca or Pteridium aquilinum dominant communities and certain families such as 'A' and 'D' graze communities not normally grazed at a high intensity by the remainder of the flock. Although Pteridium aquilinum dominant and Agrostis-Festuca communities occur within the boundaries of their normal territories both these families graze them well below normal intensity. This indicates that some factor other than nutritive value, palatability, or productivity governs the extent to which some families graze the various communities. The significance of these 'preferences' and the reasons for them will be discussed later.

CHAPTER 1

Part 3

Effect of herding and feeding hay on family home range behaviour.

An important factor in the development of home range behaviour will be the amount of disturbance by man. This disturbance may be important in the development of the home ranges of the Gairs sheep which are regularly shepherded.

It was frequently observed that the normal daily herding had little effect on the dispersal of the families. The practice of moving the ewes up or down the hill merely moved them to the top or bottom of their respective territories. During herding, ewes grazing adjacent areas bunched in small groups of 15-35 ewes depending on the portion of the heft concerned. The groups were larger in the centre of the heft and on the Agrostis-Festuca areas, as larger numbers of ewes grazed these. It is suggested that such small groups of ewes are a definite unit and that they possess closely allied grazing and resting territories. Attempts to determine this structure by marking every ewe on the heft failed because of the practical difficulties of identifying the ewes at the ranges involved.

The effect of the much closer herding practised when the rams (or tups) were on the hill could possibly have a more marked effect on the distribution of the various families and could be a factor leading to the breakdown of the family association.

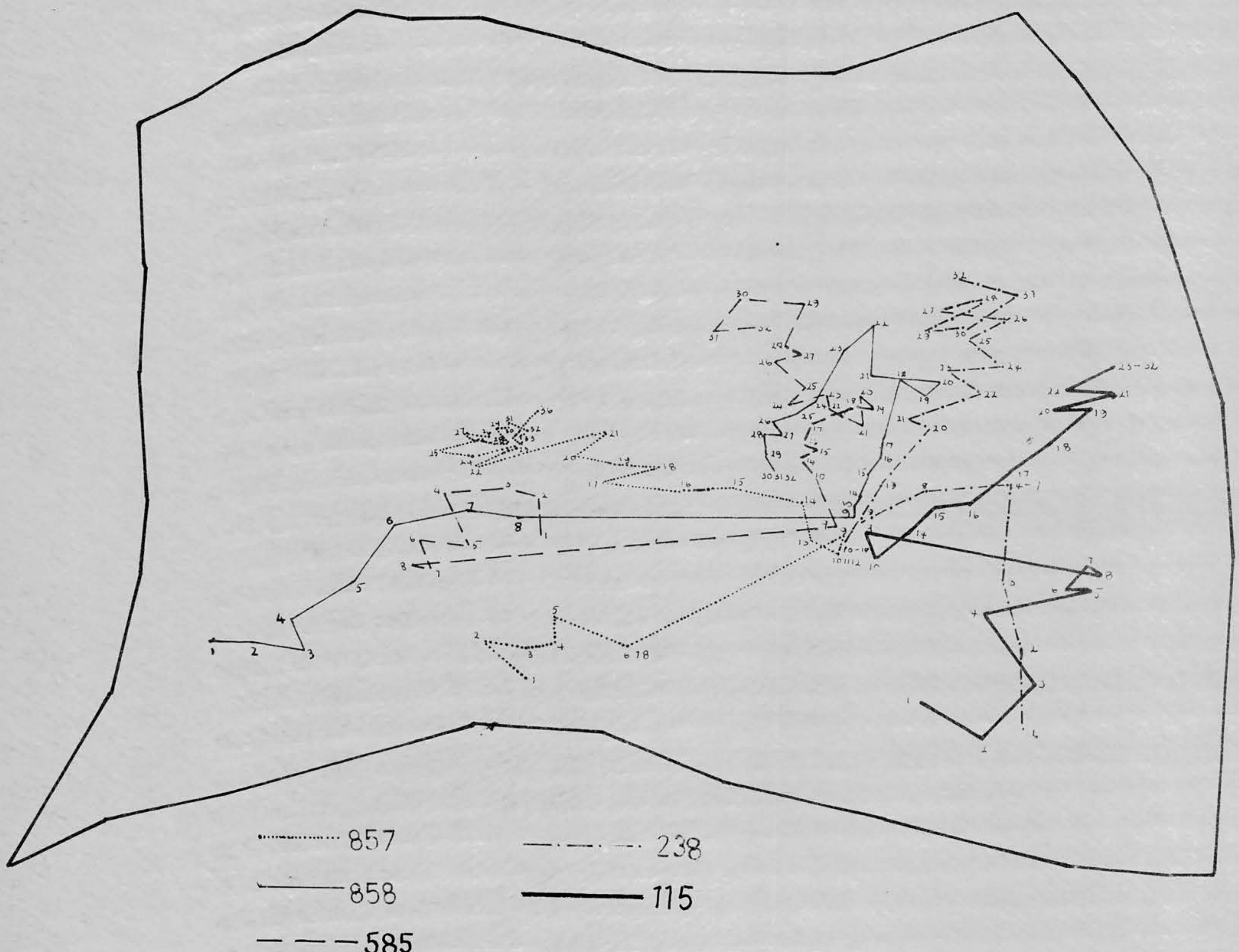
Three opportunities arose to record the effect of this type of herding on the sheep and one to record the response to hand feeding of the ewes, at a fixed point at the bottom of the Dod hill.

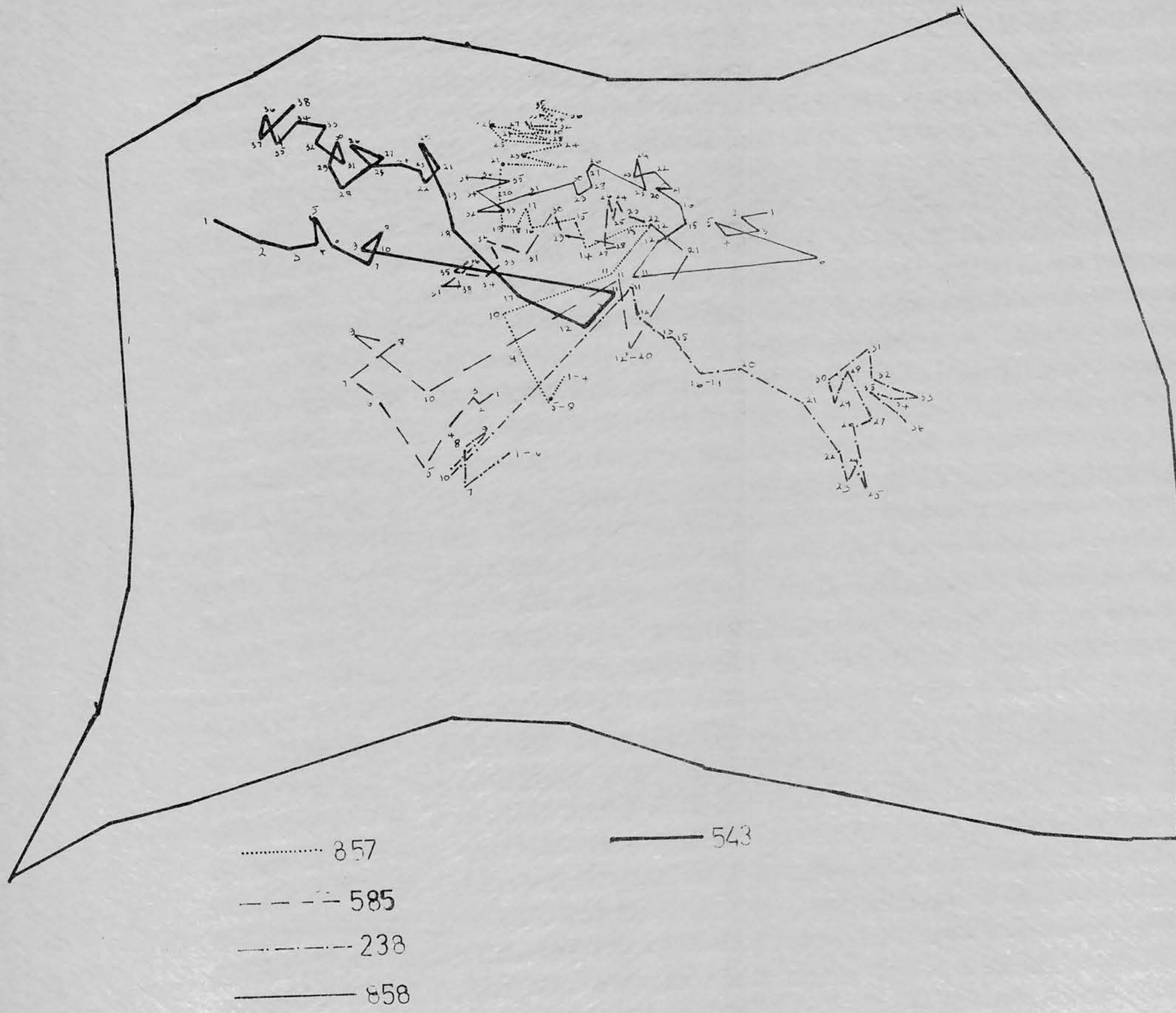
Five sheep were observed throughout the day, recordings being made every 15 minutes. It was hoped to observe the same ewes on each occasion but this was difficult as one ewe might not be found for some time. The five sheep observed were therefore chosen from the first five seen among the following.

Family	Ewe No.
'A'	543
'C'	115
'D'	857
'E'	858
'G'	585
'H'	238

The results are given in Diags. 13 to 16, pages 54 to 57, taken directly from the projection produced by the sheep recording apparatus reduced to 1/9 actual size. The numbers run from one to thirty-seven and represent the position of each sheep at observations made every 15 minutes. The lines joining them are given as straight on the maps but this would not necessarily be the path taken by the sheep.

At herding all the ewes were brought to a convenient gathering area. The object of this was to enable the shepherd to observe both the rams and ewes to determine that mating was proceeding. Another possibly more important effect was to bring ewes at oestrus near the ram.


857
238
858
115
585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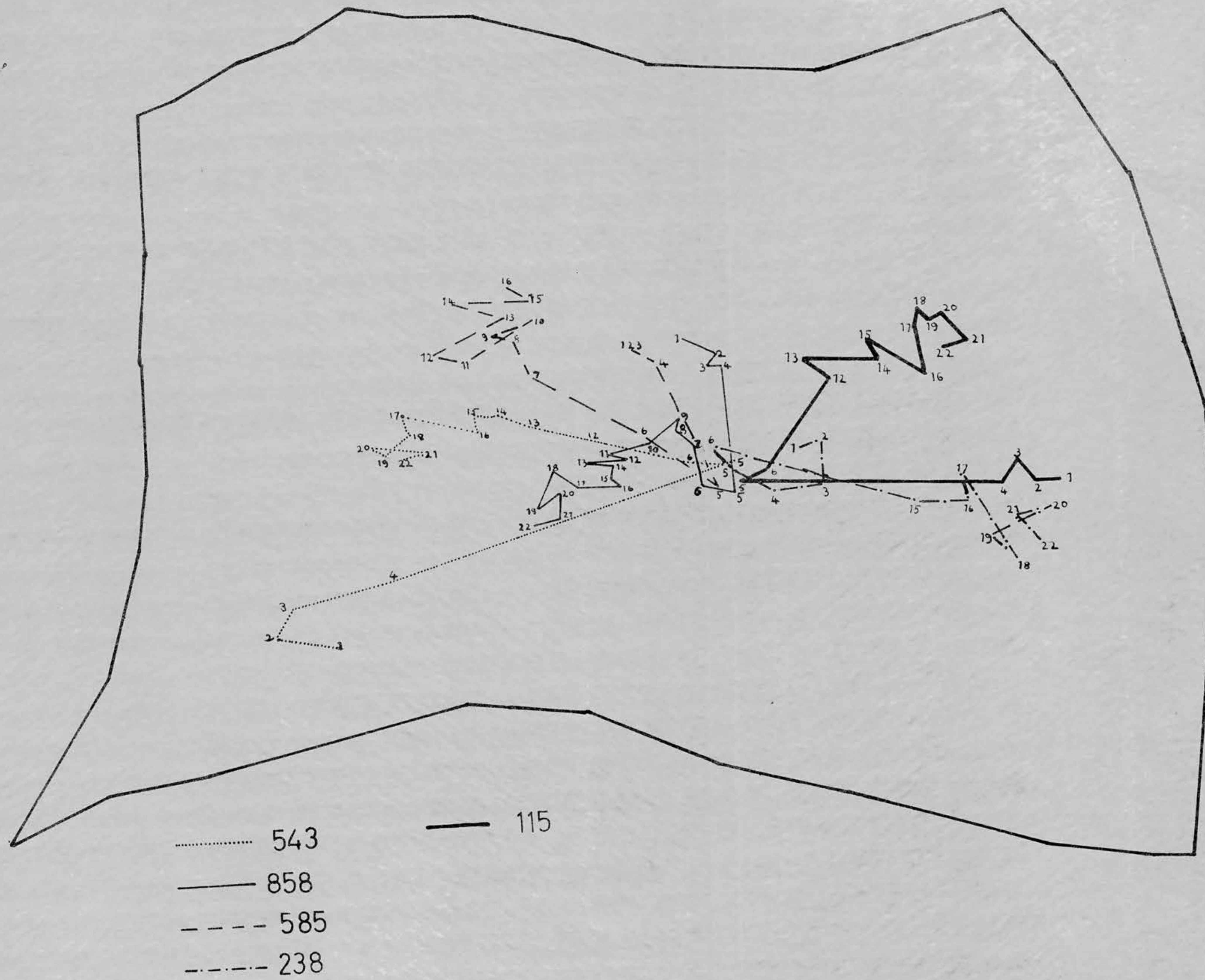
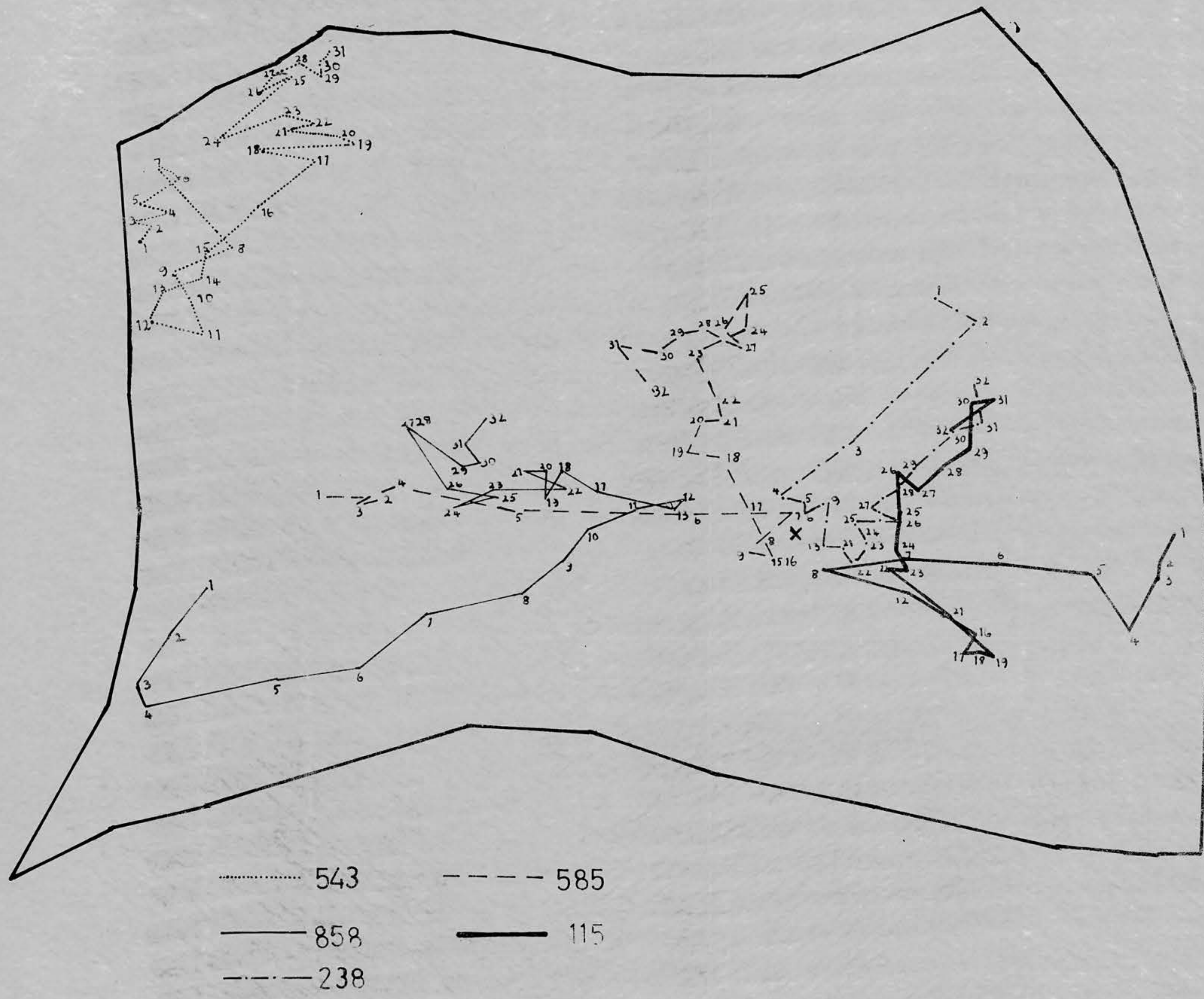
238
858
543



543
858
585
238
115



543
585
858
115
238

RESULTS

Diagram 13, 7th December, 1959.

The area to which the sheep were gathered is very close to the pens at the foot of the Dod hill (map 2) and is represented by the observation numbered 9. The ewes had approximately 2½ hours of daylight in which to graze before herding was carried out and they had all commenced grazing in their respective home ranges. Almost without exception the effect of herding was to cause the ewes to lie down after the dog and shepherd had left, the time varying from 45 minutes in the case of ewe No. 857, to 2½ hours in the case of ewe No. 238. Both these ewes had been lying just before the disturbance but had grazed previously to this.

In the case of three ewes the disturbance was considerable, i.e. they were completely removed from their normal home range on the Gairs to the Dod. Of these sheep, 857 and 585 returned to their normal rake within two hours and were moving in this direction immediately after lying down. No. 858 at first moved with the Dod sheep but within three hours of herding was beginning to cross the burn and reoccupy its normal home range. The two Dod sheep were still well within their normal home range and spent a longer resting period than the more disturbed Gairs ewes.

Diagram 14, 15th December 1959.

Because of good visibility it was possible to commence observations earlier and finish later. The ewes were gathered to a point high on the Gairs above the field at 10.15 - 11.00 hrs.

This is represented by the 11th observation. Only one ewe was outside her normal location (No. 238) and in fact was grazing on the Gairs when herding took place. She returned to the Dod after herding. The effect was much the same as before i.e. a lying down period soon after removal of the dog and then a return to the normal grazing area. This was particularly marked in the case of ewe No. 543 which returned quickly to the home range she normally occupied, at the top of the Gairs.

Diagram 15, 30th December, 1959.

The heft was herded earlier than usual at 10.00 hrs. and observations were only possible from 9.00 - 15.30 hrs. The area to which the sheep were herded was on the Gairs/Dod boundary and disturbance was lower than usual. However one of the Dod sheep (No. 115) was gathered from some distance and after the normal lying period moved quickly back. No. 238 was grazing close to the gathering area but after a long rest period ($2\frac{1}{4}$ hrs.) she travelled a considerable distance before commencing grazing.

Diagram 16, 29th January, 1960.

Hand feeding of the sheep on this heft took place only during severe weather at the discretion of the shepherd. During prolonged rain or high winds in early spring supplementary feeding with good hay was practised. Concentrates were not fed on any occasion. Readings for the family distribution maps were not carried out at first during the periods of supplementary feeding until it became obvious that the feeding was not grossly affecting the distribution of the families. Only three sheep out of the five visited the feeding area (X) and of these, only 585 left her normal home range. Ewe No. 543 made no attempt to make the lon long journey from the top of the Gairs and was only one of fifteen - twenty ewes which were also grazing near the summit. Although 858 moved in the direction of the feeding racks she did not approach them.

Conclusions

On the three days recorded (and on numerous other occasions) neither herding nor feeding caused major modification in family distribution. Initially, bringing the ewes together caused very considerable disturbance and mixing which might be expected to disorientate them. In only one case was this recorded, ewe No. 858 on the 7th December (Diag15) joined a group of ewes moving up the Dod and only gradually moved away from the group to return to her normal home range. This type of behaviour was noticed on several occasions during normal sheep watching operations and it is to be expected that the natural gregariousness or flocking instinct will cause ewes to be 'caught up' with ewes from another territory rather than pursue an individual route back to her territory. This is likely to be even more important when disturbance of the ewes has caused them to flock. Unless the disturbance were exceedingly frequent, a permanent effect on home range is unlikely, as the ewe invariably attempts to return to her own home range within a few hours.

One characteristic effect of herding is apparent when the dog has left the sheep. The majority of ewes, after a slight dispersal from the bunch lie down for varying periods. There appears to be some connection with the distance the ewe has been removed from her normal territory and the length of time spent lying down, i.e. a ewe brought from some distance to the gathering area will normally spend less time than one within whose territory the herding area is situated. Weather conditions also affect the flock after herding. During periods of high wind and/or rain the ewes remain lying for a considerable time.

The effect of handfeeding with hay appears to be very small. It is the experience of many hill shepherds borne out by observations on the Gairs that unless the ewes need hay they will not travel long distances for it. However, ewes in whose home range the hay racks were situated did visit them, whereas ewes grazing certain areas e.g. 543, very rarely came down to the hay racks. It is difficult to believe that they were sufficiently well fed not to need supplementary food. Certainly when compared with, for example, ewe No. 115, which regularly consumed hay, it is certain that these ewes grazing a predominantly Molinia caerulea sward were on a potentially far inferior diet. If ewes, such as No. 543, came to the feeding area, the long distances involved would demand the expenditure of a considerable amount of energy. This cannot be a desirable thing with hill sheep in winter. Therefore to benefit all the ewes the hay feeding stations should be sited one to each major territory to prevent the situation shown on Diag.18, page 57, where ewes needing supplementary food were unwilling to leave their territory to obtain it.

DISCUSSION

One very important feature of hill farming in N. England, N. & Central Scotland and parts of Wales is the maintenance of a flock of ewes on an unenclosed hill by the "hefting" habit. The ewes show a disinclination to range from a particular area or heft and without this habit it is unlikely that sheep husbandry would be possible in these districts. The term hefting implies the adoption of the area by the whole flock and does not necessarily involve the aggregation into smaller social units, the heft normally being a much larger area than the home range. For example the Gairs heft is 250 acres although individual members of the flock range over a smaller area. Roberts (1947) writes that some hill shepherds with the ability to recognise individual sheep and their particular grazing area, have used this knowledge to reduce the grazing pressure on a particular portion of the hill by drafting or culling the ewe or ewes grazing the area before the normal time. The effectiveness of this procedure would depend very largely on the quality of the community and the stock density but this does not detract from the evidence of the home range habit which this affords.

It is interesting to note that two groups of ewes of two related sub-breeds namely North country and South country cheviots on the same heft at Sourhope with the opportunity to graze the same area, do in fact segregate into two distinct but overlapping home ranges. The North country breed appears to be the more aggressive (or more likely less timid) and grazes the lower and more productive areas of the heft, whereas the South country Cheviots are forced to graze the floristically inferior and nutritionally less favourable ground.

Similarly it has been noted at Glensaugh, another farm of the Hill Farming Research Organisation, that two strains of Scottish Blackface, Newton Stewart and Lewis, have different territories within a common enclosure although a certain amount of overlapping occurs. The Lewis strain occurs more frequently on Calluna-Eriophorum communities in contrast to the Newton Stewart which grazed more frequently on the Agrostis-Festuca communities.

Territorial and home range behaviour is a common feature of the social behaviour of many species of animals and birds, but it is the wild members of the Artiodactyla that provide the closest approximation to the behaviour observed in hill sheep. The only truly wild ungulates in Britain are deer (Cervidae) but both goats and Soay sheep occur in the feral state. It is useful therefore to compare the social structure and behaviour of these animals with that of the hill sheep.

The red deer (Cervus elephus) is the deer of open hills in this country and grazes many of the communities grazed by the sheep. It has been shown (Wormwell (1960), Fraser Darling, (1936)) that sheep are commonly found at a lower elevation than the deer and have access to the better communities. On Rhum the reduction in the numbers of sheep have allowed the deer to colonise the lower slopes.

Fraser Darling (1936) has shown that in many respects the situation with red deer is similar to that described for sheep.

The small groups of related females forming the definite territories within the larger heft could be applied with equal truth to either the ewes or hinds which have a similar matriarchal structure.

The species differ in their behaviour on several points. The ewes form much looser groups e.g. they are not always in the immediate vicinity of the foundation ewe or other members of the family but graze within a similar home range. Since not all the lambs of any one ewe are kept it is unlikely that as many related females can exist and the sub-groups which occur in the hill sheep flocks in contrast to deer are in fact several groups of related ewes. There is also a considerable difference in the stocking rate of the two species. Fraser Darling (1936) quotes a figure of one deer to 40 or 50 acres as a mean, varying from one to 30 to one to 100 acres, this figure in fact depending to some extent on the amount of sheep competition. Even allowing for the larger animal the density is considerably below the stocking rate of one ewe to two or four acres at which approximately 55% of ewes and hoggs in Scotland are kept (Hill Farming Research Organisation , 1958). At the lower stocking rate home range behaviour may be expected to he more pronounced.

This behaviour in hill sheep and the red deer contrasts with that exhibited by reindeer and the Rocky Mountain bighorn on the North American continent which shows little territoriality. (Palmer (1926), Packhard (1946), Spencer-Clifford (1943)).

Feral Goats occur in many parts of the country, in the Highlands of Scotland, in Wales and in Ireland. They appear to have preferences for the higher, drier ground and their family parties in contrast to deer and sheep consist of an older male, several females and kids with a few yearling males loosely attached to the group.

Soay sheep found on St. Kilda in a feral state are of a very primitive type, and might therefore be expected to show home range behaviour to a much greater extent than the domestic breeds. In 1932 a flock of 107 sheep were moved to the main island of the St. Kilda group and since that time there has been no record of any movement or interference with the flock in any way. Morton Boyd (1960) reports that the Soay has a distinct home range although the dimensions of it are not known with any certainty. The size however is said to be governed by the potential feeding value of the communities within the home range. The males normally occur in separate parties except in the breeding season and the social structure is matriarchal. The territoriality of these primitive sheep therefore resembles that in hill sheep in as far as their behaviour is at present known.

The existence of a social organisation based on the 'peck order' described by Allée (1938) has not been described in hill sheep but from personal observation and discussion it is certain that there are varying degrees of aggressiveness in sheep and little doubt that this type of social organisation or a similar one could occur in the sheep studied. If it does occur, it provides a very sound explanation for the development of the home ranges observed and would account for the less aggressive animal lower in the social order being forced on to the poorer communities or areas of less amenity by virtue of exposure etc. The acceptance of such a social organisation in sheep would account for the maintenance of the habit, for in the absence of a true family relationship it is likely that the offspring will take the social rank of the mother. The culling and selective retention of ewes and their offspring will cause changes in the structure of the flock which is also likely to induce changes in the territorial distribution of the ewes. This is in agreement with changes observed in the numbers of sheep on various communities over the last few years.

There is an obvious and real association between the lamb and its mother for the first weeks of its life and this is carried on beyond weaning. It has been observed that the close mother-daughter relationship is maintained from lambing in April to the arrival of the next season's lamb. The previous year's lamb then ceases to graze very close to the ewe and probably never does so again. Whether this split is due to the dam or the hogg is not known but the split occurs very suddenly and noticeably within a few days.

Such a close relationship between the mother and daughter for up to twelve months must result in the lamb learning the home range of the dam and subsequently maintaining this home range. Two checks of the effect of this mother-daughter relationship are possible. If a lamb was fostered it should assume the home range of its foster mother and not that of its ancestors. It was not possible to check this on the Gairs as no suitable fosterings occurred.

If a lamb were taken from the hill in the first winter, as is done in parts of Wales and Scotland, this should also break the ancestral territory as the lamb is not likely to have fully acquired the territory of its dam. Lambs wintered away should therefore return to a non-family territory. Doney (1959) working on a mountain flock in North Wales attempted to record this by recording the number of lambs gathered on the same day as their dams. The two halves of the heft were gathered on different days and the presence of lambs on the same half of the heft as their mothers would indicate that a family home range existed. Lambs were not found on the same side of the heft, which indicated that they were not associated with their dams. This cannot be considered conclusive evidence that the family territory is destroyed by wintering away from the hill, and many shepherds have said that away wintered hoggs return to their dams territory. It must be pointed out that the lambs wintered away, remain on the heft when returned to it.

The territorial habit which occurs on the Gairs and on other hefts where the system of management is similar, is therefore a continuation of the territoriality found in primitive breeds of sheep. It has probably developed by the differences in the aggressiveness of individual ewes and been inherited both by this method and by a direct maternal effect. The similarities between this type of behaviour and that in red deer in this country is very marked and it is significant that both these species graze very diverse grassland in relative freedom from predators. One can very readily conclude that this organisation results in a better utilisation of this type of sward under the conditions found in Great Britain.

Territorial behaviour is of significance to two different aspects of hill sheep production, breeding and the management of the ewe flock.

Breeding for economic characters in hill sheep is rather more difficult than the corresponding practice in lowland sheep. The normal method (if such exists) is that of selecting the ram lambs on a weight for age basis or the progeny testing of these rams (Roberts and Williams (1956)).

Similarly, ewe lambs can be selected for the retention in the ewe flock on such measurements as weaning weight, staple length and fleece weight which are said to have a high heritability in sheep (Doney (1956)). The concept of heritability however implies that the calculation of it and its development in the ewe is based on a uniform environment. Groups of sheep grazing diverse hill pasture of the type described have been shown to possess a distinctly different home range which includes different vegetation types and hence different nutritional possibilities. The extent of these nutritional differences will be considered in chapter 3, commencing on page 83. Topographical and exposure effects are in some cases as important as the nutritional ones, and different groups of sheep possessing different territories could be influenced by these differences. Lamb mortality, fleece type, and general performance are three of the economic characters whose selection and expression could be affected by exposure effects.

The splitting of the ewes into smaller groups would not have such importance if these groups were not based on related ewes, however the fact that they are based on relations, has the effect of greatly increasing any mother-daughter correlations or any based on sibs. Selection, therefore, or culling the poorer ewes could do little to improve the overall performance of the flock, as the better sheep may be inhabitants of the better territories and vice-versa. It would, therefore, be desirable when selecting ewes lambs to take into account the home range of the lambs. Utilisation of the poorer areas of the hill could possibly be improved by the selection of good lambs from the poorer home ranges. This practice would require care as a high performance on the poorer types of community is only possible at relatively low stocking rates on these communities. If the stocking rate of the poorer territory is increased without a corresponding increase in the stocking rate of the better territories (by selection) migration from the poorer territories will take place. In general then, the methods of selecting ewe replacements would be to divide the sheep by virtue of the grazing territories and select within these groups to prevent any bias in favour of the population of better territories. Obviously such a method will involve the selection of sheep not quite as suitable at first sight but will improve the overall utilisation of the hill.

The siting of supplementary feeding stations should be carefully considered. There is some justification for at least three feeding sites on the Gairs in order that each ewe may get maximum benefit from the feeding. One should be sited in the present position at the foot of the Dod, one in the region of the field and one higher up on the Gairs. With such a layout it would be possible for each ewe to reach a feeding site without leaving her home range. Hill shepherds are likely to support this practice on the grounds that it does not upset the grazing rake of the sheep. The practice is advocated, however, for the reason that some ewes will not leave their home range even to obtain supplementary food. The siting of a mineral box is also of importance, for, although the presence of one appears to effect ewes a little more than that of supplementary feeding (with hay) there are still ewes which rarely if ever attempt to obtain minerals from the box, possibly because of home range considerations. The effect of interrupting the natural rake of sheep has been mentioned in connection with cobalt deficiency and the trace element factor could be a very important one in families whose home range had herbage of a low cobalt level. Provision of mineral sources etc. could largely prevent a deficiency developing.

Any improvement in the botanical and manurial status of the hill would require consideration in relation to the social structure of the flock. Improved areas would need to be sited in the home ranges of the sub-groups, account being takan of their numbers. This would be necessary to achieve as good an overall distribution as possible and to prevent territories becoming vacant as sheep moved on to the improved areas.

At certain times of the year, mainly when the ewes are heavy with wool or in lamb, they are prone to being trapped on their backs and are unable to get upright. This accident is a very important source of loss and at these periods much of the shepherd's time must be spent in preventing it. 'Couping' as the accident is called is said to be more prevalent in certain families than in others and if this is the case it is also connected with the territory grazed. 'Couping' usually occurs on tussocky uneven ground such as that found on a Molinia caerulea dominant community and if families habitually grazed on such an area the incidence of 'couping' would be expected to be higher in that family. No critical information is available regarding the truth or otherwise of this but it does appear possible. If this proved to be a severe problem the long-term solution could be to cull families grazing the dangerous areas. This would eventually reduce the incidence although reducing the overall utilisation of the hill.

The heterogeneity of the hill sward imposes on the hill sheep grazing this sward a similar heterogeneity of behaviour and potential nutritional level which would be expected to be reflected in the heterogeneity of performance. It has not been possible to demonstrate this on the Gairs although more recently (Hunter (1962)) has demonstrated a relationship between home range and performance in Scottish Blackface ewes. It is certain that in hill sheep there remains a primitive habit which can express itself under the type of husbandry practised and to disregard home range behaviour would be unwise. Any changes in management practice should be considered in relation to this.

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CHAPTER 2.

The distance travelled by grazing ewes.

Introduction.

Wood and Woodman (1939), Linehan and Lowe (1946), Rhoad and Carr (1945) and Garrigus and Rusk (1939) have suggested the importance of assessing the energy expended by the grazing animal when moving about in search of food and give estimates of distances walked together with energy requirements. Tribe (1949) presents figures for the distances walked and the time spent grazing by the Cheviot sheep obtained throughout 24 hours regularly over a 12 month period. The sheep were kept under lowland conditions in a two acre paddock. More recently Clapperton (1961) has evaluated the energy cost of both horizontal and vertical movement in sheep and gives figures of 0.59 calories per horizontal kilogram metre moved and 6.45 calories per vertical kilogram metre moved.

The distances walked by a hill sheep during the day is, therefore, of some interest as an indication of its energy requirements. It is also useful in defining the area adopted as a grazing range by the individual sheep.

Method.

Data on the distances walked by the various ewes on the Gairs heft were obtained in conjunction with the investigation of territory reported in Chapter One.

The positions of five sheep were plotted at fifteen minute intervals throughout the 'watching' day from just after dawn to just before dusk on a total of ten days during the year. Observations were made on five days during December and January and on five days in May and June. This was done in order to obtain comparative figures for the winter and summer periods. The path recorded was measured by superimposing the gridded master sheet on the trace and calculating the distance walked from the number of 100 x 200 ft. squares traversed, horizontally, vertically or diagonally. By recording at fifteen minute intervals it was hoped that the path taken between the points was a straight line, although it was obvious that on several occasions it was not. Resting periods (considerable in some cases) were not recorded.

The five sheep recorded were 115 & 238 whose normal home range was the Dod, 543 & 306 whose normal home range was the Gairs, and 858 with a central home range.

Results.

The actual distances walked by the ewes are given in Table 7, page 76.

TABLE 7

The distances (in feet) walked by five sheep on four dates in Summer and four in Winter.

Sheep No.	SUMMER Date.	SUMMER Distance.	WINTER Date.	WINTER Distance. (inc.herding.)	Distance herded.
115	18/5/60	3240	15/12/59	1230	425
	24/5/60	3900	22/12/59	1198	
	14/6/60	3134	7/1/60	1000	
	23/6/60	3010	14/1/60	1298	
Mean		3321	Mean	1181	
238	18/5/60	3910	15/12/59	2322	902
	24/5/60	3434	22/12/59	870	
	14/6/60	3500	7/1/60	1325	
	23/6/60	3100	14/1/60	1109	
Mean		3486	Mean	1406	
306	18/5/60	4540	15/12/59	2103	770
	24/5/60	3785	15/12/59	2103	
	14/6/60	3760	7/1/60	1757	
	23/6/60	3950	14/1/60	2327	
Mean		4008	Mean	2122	
543	18/5/60	2200	15/12/59	2360	450
	24/5/60	2410	22/12/59	1956	
	14/6/60	3500	7/1/60	3200	
	23/6/60	2375	14/1/60	2640	
Mean		2621	Mean	2539	
858	18/5/60	2510	15/12/59	2640	400
	24/5/60	2380	22/12/59	1657	
	14/6/60	1995	7/1/60	3134	
	23/6/60	2219	14/1/60	3644	
Mean		2276	Mean	2768	

Table 7 shows that sheep cover greater distances during the summer period. This is to be expected owing to the larger numbers of observations made in summer. A more accurate indication of the activity of the ewes may be obtained by considering the distance walked per hour of daylight.

This figure is given in Table 8 below.

TABLE 8

Mean total distances walked (mean of 4 dates) divided by the number of hours of observations.

Sheep No.		Distances (ft.) Summer	Winter
115		192.5	181.7
238		202.1	216.3
306		232.3	326.5
543		151.9	390.6
858		131.9	462.0
	Mean	183.3	323.6

This confirms that the sheep are more active during the hours of daylight in winter than in summer, although the total distance walked is less.

The possibility exists that this apparent difference is due to the lower number of observations rather than shorter day length i.e. grazing could continue during dusk and darkness. In many cases, however, the ewes were resting for the last few observations and in some cases were seen to commence grazing in the same area on the following morning.

In general, the ewes were most active between from one hour to four or five hours after observations commenced. In winter this occupied the hours of daylight but in summer there was a second peak of activity in the early evening.

The differences between distances walked in summer and winter (both total and per hour) are significant at the 0.5% level. The differences between ewes are also significant at the 0.5% level. No significant differences exist between the four dates of each period,

It has been suggested that the distance walked may have an effect on the energy requirements of a ewe. On the basis of the distances given a figure can be calculated for the energy requirements for movement of the individual ewes using the figures given by Clapperton (1961)

The distances in Table 7 were translated into distances walked horizontally, vertically and diagonally and these distances were then expressed as the number of metres moved horizontally and vertically, using an average gradient of 1 in 6.

The average weight of ewes in the investigation was 42.5 kilograms and the energy required for daily movement was calculated on this basis. The number of calories required per ewe are given in Table 9.

TABLE 9

Total daily energy requirements for movement (calories) based on a weight of 42.5 kilograms using the values of Clapperton (1961).

Sheep No.		Energy requirement (calories)	
		Winter	Summer
115		68,145	144,208
238		53,210	54,150
306		85,441	125,635
543		76,425	53,975
858		107,530	100,340
	Mean	78,150	95,667

CONCLUSIONS

The distances walked by the individual ewes differ significantly from each other and this has an effect on the energy requirements for this purpose. The significant difference between summer and winter activity (distance walked per hour of daylight) is to be expected since ewes grazing similar territories will need to move further to obtain an equivalent dry matter intake during the winter months.

There are home range differences between the distances walked in winter which can be correlated to the possible value of the communities in the range. The two sheep grazing the Dod, 115 and

238 walk smaller distances than 306 and 543 which graze the Gairs. This difference is only apparent in winter when useful herbage is scarce. It is obvious, therefore, that home range behaviour not only affects the nutritional level but also the nutritional requirements.

It was often noted that weather conditions affected the activity of the ewes. During high winds and/or rain, grazing commenced late and usually finished early. On fine days the ewes were often grazing before observations had begun. On fine days, therefore, the figures given in the tables will not represent the true distance walked.

The observed ewes were herded with the rest of the flock on 15/12/59 which gave an opportunity to record the distance moved during this activity and hence the effect of this on the energy requirements. The distance constitutes an important percentage of the total distance walked (up to 38% in the case of 238) and consequently utilises a large proportion of the available energy. Under winter conditions, therefore, herding should be carefully considered and only done when the benefits are likely to offset the loss in energy involved.

The figures given for the distances walked are considerably less than those quoted by Tribe (1949) who studied the distances walked by sheep on a lowland pasture. Tribe's figures are approximately twice those given in this investigation and this difference would appear to be genuine. The distances given in Table 5 are certainly under-approximations for two reasons. The distance between recordings was measured as a straight line, which was not always the case and some grazing must have taken place when lack of visibility prevented recording. It is unlikely, however, that these errors are great enough to account for the differences between the distances given here and those of Tribe (1949).

It is conceivable that animals grazing poorer quality swards low in energy and high in fibre may be limited in their activity by lack of energy. The lower digestibility of the hill herbage can also reduce intake and hence increase the necessity for foraging.

The discrepancy between the walking distances given by Tribe (1949) and those obtained in this investigation are difficult to explain and may, to some extent, invalidate the energy data as absolute values. It is certain, however, that the home range differences are unlikely to be affected and these differences emphasise the importance of the habit in determining the productivity of hill sheep.

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CHAPTER 3

Part 1

The seasonal variation in the chemical composition of seven Major hill species and the relationship between composition and flowering date.

Introduction

The literature reviewed in the following pages is concerned mainly with lowland grassland species rather than hill species. Although this gives a useful guide to the results to be expected from hill grasses, information of a more precise nature is desired.

An analysis of eight important hill grasses was therefore undertaken at monthly intervals throughout two years. The grasses analysed were Agrostis tenuis, Anthoxanthum odoratum, Deschampsia caespitosa, Deschampsia flexuosa, Festuca ovina, Festuca rubra, Holcus mollis and Nardus stricta, which together provide the bulk of the grazing on the Cheviot hills.

The analyses carried out were crude protein determination, crude fibre determination, ether extract and total ash. In the absence of digestibility or total energy data these values provide a useful indication of the feeding value of each species. The collection of data on flowering dates enables a useful statement to be made on the comparative digestibility at a given date (Raymond (1960)). (See part 2.)

The accuracy of a sampling method to determine the value of vegetation to the grazing sheep is reduced by the inability to select a sample similar to that selected by the sheep. This problem although less relevant on hill pastures in winter was recognised and an attempt made to estimate the selectiveness and amount of dead material consumed by sheep. (See Appendix 6). For this reason dead material collected was analysed.

The dry matter content of the various species is of interest because of its relevance to productivity studies and because of the importance of succulence (or low dry matter content) to palatability and intake (Davies (1925)). The dry matter content of each species was determined, therefore, on a total of 6 dates in the two years.

Review of Literature

Many workers have studied the composition of grasses and associated species in lowland grassland. The effect of maturity and flowering on the composition have also been considered.

May (1853), Sutton and Voelcker (1886) and Wilson (1886) carried out the earliest useful analyses of grasses, but only Wilson provides any data on the effect of flowering on the chemical composition and digestibility (artificial digestion). Wilson's analyses indicate that compared with differences due to the stage of growth the differences between species are small, both with regard to composition and digestibility.

Kellner (1907) provides very complete information on the feeding value of lowland pasture grasses as measured by their chemical composition and noted the decrease in crude protein and digestibility as the grasses mature.

At about the same period Armstrong (1907), Hall and Russell (1912), Crowther and Ruston (1912) and Ellet and Carrier (1915) gave chemical analyses which showed the decrease in crude protein and the increase in crude fibre which occurred with flowering and developed the importance of stage of growth and frequency of cutting on chemical composition.

Woodman (1926) gives figures for starch equivalent and digestible crude protein at various stages which emphasises the decrease in feeding value and digestibility which occurs at the flowering and pre-flowering stages.

Waite and Sastry (1949) show that the amount of leaf relative to stem falls markedly with maturity in timothy (Phleum pratense) and this has an effect on the chemical composition of the whole plant. The decrease in crude protein and increase in fibre was not solely due to this, as the crude protein of the leaf showed a decrease.

Fagan and his co-workers have conducted extensive analyses of grass and herb species at intervals throughout the season. Fagan and Milton (1932) give analyses of eleven strains of lowland pasture grasses but include monthly analyses of Holcus lanatus and Agrostis species showing a minimum crude protein, maximum crude fibre content in the months of Juky and August. The maximum crude protein content in Holcus lanatus of 13.49% occurred in April. Fagan and Watkins (1932) present single dated analyses and in some cases monthly figures for a wide variety of upland and lowland species including Scirpus caespitosum, Molinia caerulea, Nardus stricta, Agrostis species, Juncus squarrosus, Hypochaeris species, Potentilla erecta, Achillea millefolium, Calluna vulgaris etc. It is shown that the leaves of many of these species are high in crude protein and ash which together with winter greenness indicates that they may be of some value.

Fagan and Provan (1932) give the crude protein content of unfertilised hill pastures at monthly intervals from June to November. This shows a variation in dry-matter crude protein of from 11.6% in November to 16.4% in June. A composite sample from November to May gave a crude protein content of 12.0% in the dry matter.

Stapledon et al (1923) give the composition of Agrostis species for five months from November to March showing a variation in crude protein of from 8.56% in December to 16.5% in March. A single analysis of the dead material of Italian ryegrass in March shows it to have a dry-matter crude protein of 8.25% and a crude fibre content of 34.05%

Elliot (1926) and Godden (1926) in a report on the chemical composition of upland and lowland pastures state that there is very little difference between the calculated energy values of the two pastures but that the cultivated swards were somewhat higher in nitrogen and markedly richer in all the mineral constituents. A hill pasture in Cardiganshire gave a crude protein content of 16.5%, a crude fibre of 24.71% and a mineral content of 4.5%. Lowland pastures in the same area show a lower fibre and a higher crude protein and ash content.

More recently Raymond (1960) has pointed out the limitations of any chemical analysis in predicting the nutritive value of grassland herbage. Data is presented showing that the nitrogen content gives no indication of herbage digestibility although a higher correlation between nitrogen content and digestibility is obtained when herbage at the same stage of growth is compared. Raymond also confirms observations by Woodman (1932) that there is a considerable drop in digestibility (½ unit per day) at ear emergence. Stapledon (1932) shows that different grass species have a different dry matter content and also that the dry matter varies from month to month. The dry matter percentage is low during the period of maximum growth in May and June and is influenced by meteorological conditions at any period of the year. Low rainfall increases the dry matter content by rendering growth negligible and is, therefore, a secondary rather than a primary factor.

Sampling method and sites.

Eight sites were chosen, two on each of the four hefts, Park Law, Hairney Law, Gairs and Rigg (see map 1). Four of the sites, used for the collection of the six species (Agrostis tenuis, Anthoxanthum odoratum, Deschampsia caespitosa, Festuca rubra, Festuca ovina and Holcus mollis), were Agrostis-Festuca communities. The dominant species were Agrostis tenuis and Festuca ovina although all the six species were common. The sites used for the collection of Nardus stricta and Deschampsia flexuosa were communities dominated by these two species, intermediate in habitat and character between the Agrostis-Festuca grassland and the drier peat vegetation.

Details of botanical composition, altitude, aspect, grazing regime and height of vegetation are given in Appendix 3.

On each site, areas particularly rich in the species desired were chosen to facilitate sorting. The herbage within a 4 x 4 cm quadrat randomly placed several times within the species rich area was cut as close to the ground as practicable with sheep shears. In general this left 5 - 10 mm. of 'stubble'.

250 grams (fresh weight) were collected from each site giving 1,000 grams when bulked, the field samples being stored in a closed polythene bag until separation. In order to reduce losses after cutting to a minimum the samples were always collected, separated and dried on the same day. It was not always possible, therefore, to collect the total required on one day. The bulk of the samples were completed on one day and the dates given in the results are the dates on which the greatest proportion was collected.

Separation, drying and analysis.

In order to reduce respiration and evaporation the samples were retained in the polythene bags in a cool room in the dark until separation. Small samples were taken from all parts of the bulk and separated into species. Only whole tillers without any dead were taken and any obvious flowering tillers were discarded. A total weight of 100 to 120 grams fresh were collected.

Drying of the samples was carried out in a standard laboratory oven pre-heated to 100°C before the samples were placed inside in perforated zinc trays. After 10 minutes the oven temperature waa reduced to 80° and drying continued until the sample was dry (constant weight). With the small samples concerned, drying was rapid. The samples were ground in a normal laboratory mill using a 1/32nd inch screen and stored in airtight bottles until chemical analysis could be undertaken. The dry matter content of the samples was taken on three dates in the year. A regular dry matter determination would have little value, as on many occasions excess moisture was present. The dry matters given were calculated when no surface moisture was present.

Duplication of the chemical analyses would have strained the analytical resources and, therefore, sampling over two years provided suitable duplication, to remove some of the objections to a single analysis.

Analysis of the samples was carried out by the methods recommended by the Fertiliser & Feedingstuffs Regulations 1955 with minor modifications as suggested by experience.

Results

The monthly crude protein, crude fibre, ether extract, ash and nitrogen free extractives (N.F.E.) of the seven species are given in Appendix 5. The monthly averages of the two years are given in Tables 10 to 15, pages 90 to 92. The results for dead material are given in Table 16. Dry matter contents are given in Table 17.

TABLE 10

% CRUDE PROTEIN IN EIGHT HILL SPECIES (AVERAGE OF TWO YEARS ANALYSES)

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Agrostis tenuis	10.7	10.75	11.9	14.65	14.0	15.2	15.75	18.7	16.7	11.3	10.85	9.8
Anthox odoratum	11.75	11.55	12.3	15.55	12.4	13.15	16.9	20.5	14.7	8.95	9.75	10.0
Deschamp caesp.	8.3	9.75	9.65	11.25	12.15	12.4	19.75	16.65	17.0	10.5	8.75	8.65
Deschamp flex.	11.2	11.5	13.0	14.85	14.4	15.35	17.3	18.05	14.2	10.75	10.05	10.25
Festuca ovina	10.15	10.6	10.35	10.3	11.05	13.45	14.15	14.05	12.85	9.4	10.7	10.65
Festuca rubra	11.25	11.5	13.1	17.35	16.1	15.85	18.0	20.2	14.45	11.1	10.5	10.45
Holcus mollis	11.05	13.0	16.7	18.1	19.3	20.25	21.55	17.6	16.8	14.6	12.2	8.0
Nardus stricta	9.8	10.45	9.7	11.3	11.0	14.05	17.5	16.15	15.05	9.0	9.5	8.8

TABLE 11

% CRUDE FIBRE IN EIGHT HILL SPECIES (AVERAGE OF TWO YEARS ANALYSES)

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Agrostis tenuis	23.65	20.0	19.3	22.5	24.2	27.05	24.8	23.0	26.45	27.8	31.65	32.3
Anthox odoratum	23.75	25.75	25.25	21.6	20.55	28.15	23.85	21.15	28.1	31.5	38.85	29.9
Deschamp caesp.	31.25	31.4	31.4	27.9	30.7	32.1	31.8	24.75	22.05	27.6	28.9	33.0
Deschamp flex.	25.4	26.6	25.5	23.3	24.55	30.0	26.45	22.0	24.35	29.9	27.15	22.15
Festuca ovina	28.45	27.0	26.45	29.15	28.25	29.05	28.2	27.2	29.75	30.85	28.5	30.1
Festuca rubra	35.25	28.8	27.6	24.0	25.0	27.3	26.35	25.7	24.85	29.8	30.05	34.2
Holcus mollis	28.8	25.25	22.75	20.8	19.65	20.25	19.05	20.6	26.5	25.3	25.85	29.75
Nardus stricta	32.75	27.05	24.05	21.75	26.25	30.35	25.25	27.4	34.7	39.1	34.15	33.05

TABLE 12

% ASH IN EIGHT HILL SPECIES (AVERAGE OF TWO YEARS ANALYSES).

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Agrostis tenuis	7.15	6.6	6.45	6.75	6.75	7.9	7.35	6.95	7.35	7.0	7.25	7.25
Anthox odoratum	7.1	5.0	5.25	6.3	5.75	6.1	6.0	5.6	5.8	5.75	6.1	6.1
Deschamp caesp.	5.55	5.2	5.25	5.7	5.35	5.0	5.75	7.6	6.8	5.95	6.2	6.2
Deschamp flex.	5.1	4.65	5.5	5.35	4.6	4.1	4.0	3.75	4.85	6.15	7.0	4.6
Festuca ovina	4.1	4.45	4.5	4.55	4.55	4.8	5.0	5.05	4.5	4.8	4.15	4.2
Festuca rubra	7.7	5.55	6.4	5.5	6.15	7.15	6.1	5.7	5.15	4.4	5.35	4.8
Holcus mollis	10.0	8.05	5.95	7.75	8.65	8.6	8.55	8.0	8.05	6.3	7.45	7.15
Nardus stricta	6.4	6.0	5.95	5.75	5.9	4.95	4.7	5.05	5.4	5.7	7.55	6.65

TABLE 13

% ETHER EXTRACT IN EIGHT HILL SPECIES (AVERAGE OF TWO YEARS ANALYSES).

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Agrostis tenuis	1.85	1.95	1.85	2.4	2.5	1.7	2.3	2.65	2.75	2.05	1.9	1.9
Anthox odoratum	1.8	2.1	2.25	2.25	1.9	1.95	2.25	2.5	1.9	1.7	1.75	1.85
Deschamp caesp.	1.75	1.75	2.05	1.8	1.85	1.8	2.1	2.05	2.05	1.6	1.7	1.5
Deschamp flex.	3.2	2.8	2.85	3.3	3.25	2.8	3.15	3.0	2.6	2.15	2.4	2.8
Festuca ovina	2.7	2.65	2.6	2.3	2.85	3.05	2.7	2.6	2.3	2.4	2.5	2.55
Festuca rubra	2.05	2.45	2.95	2.8	2.8	2.65	2.8	2.8	2.6	1.95	1.85	1.8
Holcus mollis	2.05	2.3	2.45	2.15	2.75	2.9	2.85	3.0	3.0	2.2	2.25	2.1
Nardus stricta	0.9	1.05	1.1	0.95	1.05	0.95	1.1	1.0	1.6	1.05	1.05	1.2

TABLE 14

% NITROGEN FREE EXTRACTIVES (N.F.E.) IN EIGHT HILL SPECIES. (AVERAGE OF TWO YEARS ANALYSES)

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Agrostis tenuis	56.65	60.2	60.0	53.7	52.55	55.1	45.3	48.7	46.75	51.85	48.4	48.75
Anthox odoratum	67.00	55.2	54.95	60.2	59.9	50.8	50.9	50.75	49.5	53.45	43.55	52.15
Deschamp caesp.	53.4	51.9	57.15	53.35	49.95	48.7	45.7	50.15	52.1	52.35	54.55	55.65
Deschamp flex.	55.1	54.45	54.6	53.2	53.05	47.75	48.6	53.2	54.0	51.05	51.9	55.2
Festuca ovina	54.6	55.3	58.6	54.0	53.2	49.65	49.95	51.1	51.55	52.85	54.15	52.5
Festuca rubra	50.4	51.7	52.7	44.35	56.55	52.05	46.75	45.6	52.95	53.25	46.25	49.25
Holcus mollis	49.8	52.9	51.65	50.7	46.45	48.0	48.0	50.8	45.65	51.6	52.25	49.6
Nardus stricta	50.15	55.45	59.1	60.25	55.8	45.8	51.45	50.4	40.0	45.15	47.85	50.3

TABLE 15

ANALYSIS OF MIXED DEAD MATERIAL (AVERAGE OF TWO YEARS ANALYSES).

Dead	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
% Crude Protein	6.35	6.15	5.35	5.45	6.35	7.55	7.1	6.9	6.45	6.3	6.05	6.1
% Crude Fibre	36.15	36.65	36.1	36.2	36.3	36.2	36.53	35.9	36.5	37.1	34.0	36.6
% Ash	6.5	5.95	6.15	6.25	6.0	6.5	6.25	6.2	6.0	6.2	5.85	5.65
% ETHER EXTRACT	1.55	1.1	1.25	1.25	1.05	1.4	1.45	1.5	1.25	1.6	1.15	1.35
% N.F.E.	49.45	50.15	50.35	47.8	50.3	48.35	48.65	49.5	49.8	48.8	52.9	50.8

TABLE 16

DRY MATTER CONTENT OF EIGHT MAJOR HILL SPECIES

	Agrostis tenuis	Festuca ovina	Festuca rubra	Nardus stricta	Deschampsia caespitosa	Deschampsia flexuosa	Anthoxanthum odoratum	Holcus mollis
22/10/59	35.0	35.8	31.9	42.6	37.0	34.3	28.0	22.0
27/4/59	33.3	25.0	30.1	36.5	29.5	29.2	24.5	23.7
28/7/59	36.0	38.0	34.2	40.0	33.5	34.1	27.6	24.0
9/11/59	35.2	31.0	29.6	40.1	36.8	30.5	27.5	23.1
18/4/60	30.5	23.0	36.7	34.7	30.3	28.1	21.2	22.0
25/6/60	31.4	21.0	27.1	36.6	30.1	34.2	26.6	21.7
Average	33.5	28.9	29.9	38.5	32.9	31.8	25.9	22.8

Tables 10 - 14 show that there are considerable differences in the chemical composition of the species considered and considerable variation within each species from month to month. This is to be expected and confirms analyses of lowland grasses reported (e.g. Woodman (1932), Fagan et al (1932) and Stapledon et al (1924)).

The crude protein is generally highest in March, April and May but variation occurs within these months between species. Crude fibre and dry matter are at a low level during this period also. Ether extract in general is at a maximum at this same period. The high level of ash reported by Fagan et al (1932) coinciding with the crude protein peak did not show consistently in this investigation. The nitrogen free extractives (carbohydrates) are in general at a low level during March, April and May.

Much more important to the hill ewe is the increase in crude protein, ether extract and total ash which occurs in December or January. At this period many species are higher in crude protein than they are in July. This is obviously of great significance to the hill ewe in providing a relatively high quality diet at this period.

The importance of flowering date on composition is well known and the effect of flowering appears in these analyses. The months of May, June and July are the principal flowering months with June being the month in which most species flower.

In every case the onset of flowering causes a lowering of crude protein and ether extract content and an increase in crude fibre and nitrogen free extractives. This lowering of quality is most marked in the lower quality species such as Deschampsia caespitosa and Nardus stricta.

Deschampsia caespitosa drops from 17.0% to 10.5% a drop of 6.5% crude protein (2 year avge.) in the month of maximum flowering and the crude fibre increases from 22.05% to 27.6% an increase of 5.55%. Nardus stricta drops 6.05% in crude protein and increases by 4.4% crude fibre. A better quality species such as Holcus mollis shows only a slight decrease in crude protein (2.2%) in the flowering month and decreases in fibre at this time by 1.2%.

This drop in compositional quality at flowering, coupled with the sharp decrease in digestibility at this time must severely reduce the feeding value of the herbage.

Although the crude protein maximum and crude fibre minimum occurred at the same period in both 1959 and 1960 (March, April and May) it can be seen by consulting Appendix 4 that the crude protein percentage was in general higher in 1960. This difference in composition does not apply to the crude fibre, oil or ash components which show similar values at this period in both years. Consideration of the weather data for these years (Appendix 1) shows that the spring and summer of 1959 were drier than the corresponding period in 1960. This resulted in reduced growth and the production of more flowering tillers. The low rainfall may therefore account for the lower crude protein and higher crude fibre content in that year.

Individual species.

Agrostis tenuis:

This species flowers later than most of the grasses considered and is the commonest constituent of heavily grazed Agrostis-Festuca communities.

It is a nutrient-rich species at its peak in April, providing an average crude protein content of 18.7% with a crude fibre content at this time of 23%. The oil and ash are also high during this month.

During the months of December, January and February, however, the crude protein and ether extract contents are lower than that of species such as Holcus mollis, Anthoxanthum odoratum, Deschampsia flexuosa and Festuca rubra. It has generally high dry matter and over most of the year is one of the more useful members of the flora.

Anthoxanthum odoratum:

Anthoxanthum odoratum is similar in composition to Agrostis tenuis. However in general it has a higher crude protein content particularly during December and January and in April. At both these periods Anthoxanthum odoratum has a lower crude fibre content however. The ether extract and ash content is lower than that of Agrostis tenuis. This together with its early flowering date reduces its value during the greater part of the year.

Deschampsia caespitosa:

This species is little grazed by sheep, possibly due to its high fibre content. For most of the year it has a higher crude fibre content than any other species although in May it reaches a low level of 29.05% (two year average). The crude protein is generally low, reaching a maximum in March of 19.75%. In spite of this reasonably high maximum, because of its high fibre and low oil content the species is not very useful for sheep.

Deschampsia flexuosa:

This species is not considered a useful grass. Certain features do, however, commend it. It has a consistently high ether extract and a reasonably high crude protein content particularly in Winter. Its minimum crude protein content in July is 10.05% and its maximum in April is 8.05%. The high oil and protein content in Winter together with its normally high dry matter content (31.8% average) increases the importance of this species at this critical time. The ash content is lower than many of the species considered.

Festuca ovina:

Together with Agrostis tenuis this is one of the main constituents of the productive Agrostis-Festuca swards.

The range of composition is lower than that of the other species and in general it has a lower feeding value. The average crude protein content varies from 9.4% to 14.15% in a dry matter content of 28.9% (average) with a correspondingly high fibre percentage. The ash content is below that of most of the species analysed but the ether extract content is comparable with that of all the other grasses. As a relatively late species it cannot make a useful contribution to the sward in early spring.

Festuca rubra:

Although less frequent in the swards studied than *Festuca ovina*, its quality is higher. At its peak, it has a crude protein content of 20% with a low fibre content, which is some 6.7% higher in crude protein than the previous species. The ether extract and ash content is comparable to the better grasses although below them. It has a dry matter content of 29.9% average which is a little above that of *Festuca ovina* but below *Agrostis tenuis*. It has the disadvantage of lateness in the spring but at flowering the low number of seed heads may render it more palatable.

Holcus mollis:

Holcus mollis is of a uniformly high crude protein content and in only two months of the year does it not possess the highest percentage of this nutrient. The crude fibre is low throughout the year and the ash content considerably above the remainder of the grasses.

Because of the earliness of its growth in spring and its winter greenness combined with low dry matter and high palatability, *Holcus mollis* is a valuable sward constituent.

Nardus stricta:

This grass has a very poor qualitative analysis. The crude protein is usually low and although it reaches its maximum of 17.5% in March, it possesses a crude fibre of 25.25% at this time and reaches the very high level of 39.1% in June. The ether extract content at its highest level in May, is lower than the lowest figure for any other species. Although Nardus stricta is often regarded as a mineral deficient species, this does not show in the analysis given. Although it makes early growth, its quality renders it of little value even in the early spring.

CHAPTER 3

Part 2

Flowering dates of the major hill species.

Introduction

Wilson (1886), Kellner (1915) and Woodman (1932) among others have shown the importance of the flowering date on compositional quality of herbage. Raymond (1960) has given data to show that a considerable drop in digestibility occurs at ear emergence.

For this reason data were required on the flowering dates of the various species concerned in Part 1. The data were collected on the sites sampled for chemical analysis and details of botanical composition etc. are, therefore, given in Appendix 3.

Method

A string knotted at random along its length of 15 feet was used as a transect. The string was pinned at one point in the community and the string stretched and pegged at its other end. At every knot, the tillers inside an open ended quadrat of 3 mm. x 3 mm. were counted and their species determined. Observations on their flowering condition were made. Four phases were noted:

1) Vegetative (no spikelet detected).
2) Spikelet formed in leaf sheath.

3) Spikelet emerged.

4) Post anthesis.

One hundred tillers of each species were recorded on each site and the average percentage in the critical phases calculated. There were no consistent differences between the sites either in number of flowering tillers per hundred or in the time of maximum flowering.

Results.

Tables 17 and 18 show the % of tillers with the spikelets fully emerged on a series of dates in the years 1959 and 1960.

Although the flowering pattern is basically similar in both 1959 and 1960 there are certain differences. Flowering is at a maximum in all the species in the months of May, June and July but in 1959 the peak occurs somewhat later. For example Nardus stricta reached its flowering peak in 1959 on the 3rd June but in 1960 its peak occurred on the 12th June some nine days later. All the species showed this pattern except Agrostis tenuis. In 1959 also, all the species with the exception of Agrostis tenuis show a higher proportion of flowering to non-flowering tillers. The differences between the two years was 5 - 10%.

The species with the most restricted flowering season are Nardus stricta and Holcus mollis (both years) whereas Agrostis tenuis has the least restricted flowering season in both years.

Climate is most likely to have affected the flowering date of the species in the two years and one difference is in the rainfall. Meyer and Anderson (1952) suggest that water shortage affects vegetative rather than reproductive differentiation. It is suggested, therefore, that in 1959 owing to the lower rainfall, reproductive or flowering shoots were produced at the expense of the vegetative growth. This accounts for the earlier date and larger number of seed heads.

TABLE 17

1959 % OF TILLERS WITH SPIKELETS FULLY EMERGED (EXCLUDING POST ANTHESIS STAGES) (Average of four sites)

Date	Agrostis tenuis	Anthoxanthum odoratum	Deschampsia caespitosa	Deschampsia flexuosa	Festuca ovina	Festuca rubra	Holcus mollis	Nardus stricta
May 6th	-	38.25	-	6.00	6.00	-	-	13.00
May 21st	4.00	46.50	6.00	6.00	18.00	-	6.00	40.00
June 3rd	-	32.00	-	52.00	54.25	6.75	26.00	78.00
June 15th	9.00	20.00	22.00	76.25	58.50	14.00	40.25	12.00
June 25th	10.25	13.25	18.00	73.00	55.75	25.00	20.25	3.00
July 3rd	19.50	3.25	11.25	65.25	45.00	24.75	10.75	0.75
July 11th	29.00	2.00	6.00	65.50	35.00	11.00	8.50	0.50
July 24th	30.25	-	4.50	20.75	12.00	-	6.25	1.00
July 31st	29.00	-	2.75	2.00	10.25	-	5.00	-
Aug. 6th	12.50	-	-	-	-	-	-	-
1960								
Apr. 15th	-	10.00	-	-	-	-	-	3.00
Apr. 30th	5.00	35.00	-	9.00	1.00	-	-	20.00
May 18th	9.00	36.00	3.00	23.00	6.00	7.00	16.00	28.00
June 12th	20.00	38.00	8.25	51.00	40.25	10.00	43.25	64.00
June 19th	30.25	25.00	13.50	60.25	42.00	15.00	45.00	55.00
July 1st	30.50	16.75	23.00	57.50	45.75	16.25	30.00	10.00
July 12th	32.00	10.25	5.50	50.00	26.50	20.00	10.25	4.50
July 24th	31.25	7.50	4.25	36.50	10.00	2.25	5.00	2.00
Aug. 13th	10.25	-	5.00	3.25	9.00	2.50	-	-
Sep. 2nd	5.25	-	-	-	-	-	-	-

Conclusions

In any assessment of the value or otherwise of the hill species a comparison should be made with comparable lowland species. In general, lowland spécies might be expected to have a superior analysis and there is some evidence that this is so. There are, however, some data which show that during the critical months of March and April some lowland grass species are not superior in all constituents. In Chapter 3, Part 1, hill species have been shown to vary in crude protein from 8.0% (Holcus mollis in August) to 21.55% (Holcus mollis in March), in crude fibre from 19.05% (Holcus mollis in March) to 39.1% (Nardus stricta in January), in ash from 4.0% (Deschampsia flexuosa in March) to 10.0% (Holcus mollis in September), in ether extract from 0.9% (Nardus stricta in September) to 3.3% (Deschampsia flexuosa in December), and in Nitrogen-free extractives from 43.35% (Anthoxanthum odoratum in July) to 67% (Anthoxanthum odoratum in September). Fagan (1932) gives analyses for species in a lowland "rough pasture" which had a fertiliser treatment of 6 cwt. basic slag/acre and 2 tons lime/acre. Holcus lanatus and Agrostis species were analysed and it is shown that the Holcus lanatus varied in crude protein from 4.55% in July to 13.49% on April 30th; crude fibre varied from 22.94% on April 30th to 32.7% in July, and ether extract varied from 7.26% - 12.33%. The lowland species, therefore, are superior only in the ash constituent.

An analysis of Italian ryegrass by Stapledon et al. (1924) shows that in March the composition of this grass is only superior to the better hill grasses in ash content.

The quality of the hill grasses analysed, therefore, is comparable to some lowland grasses at a similar growth stage in all constituents except ash. Only Holcus mollis approaches the ash percentages quoted by these authorities for lowland grass species.

The assessment of the most nutritious species analysed depends upon the factor considered most important to the sheep. Although a high crude protein and low crude fibre combined with a high oil and ash content is desirable, these must occur together and at a period of the year when most required. The most critical period for the hill ewe is December to April - the winter months and the months immediately preceding lambing. It is surprising that all the hill grasses are high in quality during this period and in particular the crude protein content rises in December. Two species, Holcus mollis and Festuca rubra are superior at this critical period. The rise in crude protein at this period is of considerable interest and is possibly the factor enabling the ewe to survive under the conditions occurring on the hills. The cause of the rise was not investigated but may be due to translocation of food material from the dying tillers and leaves.

The species lowest in feeding value are more difficult to determine as some species are low in crude protein but also low in crude fibre. Because of their low ash and ether extract and high crude fibre, rather than their crude protein deficiency, Nardus stricta and Deschampsia caespitosa are possibly of lowest feeding value although both Festuca ovina and Deschampsia flexuosa cannot be rated highly, at this critical period. The analysis of dead herbage shows that it is inferior to green herbage nutritionally. It has a uniformly low crude protein content varying between 6.05% and 8.45% with a very high crude fibre. The ether extract and ash content, however, is better than certain of the green species. Nitrogen-free extractives which are mostly soluble are lower in the leached dead material than in the green. If a ewe therefore took in large amounts of dead herbage either accidentally or deliberately, it would considerably reduce its nutrient intake as in general the difference between species when green is less than the difference between dead herbage and green herbage. An assessment of the amount of dead herbage taken in by the grazing sheep would therefore provide useful information on their nutrient intake.

The importance of flowering on the feeding value of the grasses has been discussed and must, therefore, be considered. None of the hill species considered were approaching maximum flowering during the months of March and April (lambing and pre-lambing months) and, therefore, the digestibility of all the species is likely to be high at this time. During the late spring/summer period when in general the herbage quality is low, the flowering pattern is of considerable importance in ensuring a supply of digestible nutrients. The spread of flowering between, for example, Anthoxanthum odoratum with a peak in May and Agrostis tenuis with a peak in July ensures that, by varying the herbage species grazed, the sheep is able to obtain the requisite digestible nutrients. Agrostis tenuis has the valuable feature that its own flowering is spread over a long period thus enabling material of high digestibility to be obtained from one species throughout the summer. There is no doubt that part of the traditional value of a hill with mixed herbage is in the differences in digestibility and composition of the various species caused by differential flowering. This results in the spread of maximum nutritional value over a longer period.

The dry matter figures given show much the same pattern as those reported by Stapledon (1924). The % dry matter is highest in the summer, autumn and winter figures than in Spring for all species, although variations do occur between species. It is shown that the dry matter in the dry spring of 1959 is higher in most species than in 1960 which confirms Stapledon's observations. The correlation between high nutritive value (in dry matter) and low dry matter occurs within species but also between species; for example Holcus mollis has an average dry matter of 22.8% whereas Nardus stricta has an average dry matter of 38.5%. Dry matter content is likely to be more important from the point of view of palatability or intake rather than nutrient yield. As a preliminary to more exact determinations of composition and digestibility the above investigation provides at least comparative values for the various species and hence the comparative value of the communities dominated by them. In Chapter 5 an attempt has been made to reproduce the qualitative intake of a grazing sheep by a sampling method, thus adding to the value of the species analysis.

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CHAPTER 4

The grazing method, species selection and amount of dead herbage consumed by free and tethered sheep.

Introduction

The preferences shown by individual sheep among the various plant associations has been discussed in Chapter 1. It is of interest, however, to determine the extent to which the sheep selects species within the community since if there is a definite species preference there will be a possibility of determining the nutrient intake with accuracy. Observations were, therefore, made on the species selected by four tethered sheep.

The main purpose of the observations however was to determine the method and frequency of biting and the degrees of dead/green selection practised. With this information it was possible to produce a sampling method at least approaching the diet of the grazing sheep on grassland of the types considered. The tethered sheep provided the bulk of the information although free-ranging sheep were studied on several occasions.

Review of the Literature.

It has long been realised that the method of grazing and the species grazed are essential factors affecting the nutritional intake of sheep.

Linton (1918) gives much valuable information on the grazing of many hill species and discusses their palatability and importance at certain times of the year.

Stapledon (1947), Grazier (1926) and Ellison (1948) all place great emphasis on the importance of palatability when assessing the nutritive value of plant species and imply that this is of greater importance than chemical composition. Stapledon as well as Ellison report that the animal has an instinct to select the most valuable species. Tribe & Gordon (1950) quote evidence in contradiction of this and show that food preferences of an animal are not a guide to the nutritional value of the food. Davies (1925) also states that the selection of the most nutritious herbage is largely accidental and probably related to low dry matter rather than any chemical characteristic.

Attempts have been made by several authorities to determine the palatability of hill species.

Milton (1925) used a visual scale measuring the amount eaten and Tribe (1950) made direct observations of grazing sheep to determine the species eaten and also suggests the use of oesophageal fistulae to assist in determining the grazed species.

McLeod (1955) and Norris (1943) have investigated the rumen contents of slaughtered or rumen-fistulated animals and Martin (1955) used a method involving the identification of cuticle remains in the faeces.

In order to reduce the difficulty of observing free ranging sheep, certain authorities have investigated the use of tethered sheep.

Davies & Trumble (1934) used a light chain 53 ft. long which allowed the animals 7 - 15 days grazing. The sheep (Merinos) soon grazed normally but bruising of the herbage by the chain caused some difficulty. Jones (1937) used a tether 12 ft. long, moved 6 ft. twice daily to ensure uniform grazing. The Welsh mountain sheep were trained to this tether in three or four days. Armstrong & Thomas (1952) used Scottish blackface wethers with a large leather collar attached to a 15 ft. tethering rope. This was secured to an iron ring fitting over conduit piping driven securely into the ground. This method of attachment reduced jamming of the rope. The wethers were tethered in pairs and moved every five days.

Although palatability is relative and influenced by the individual concerned, stage of growth, alternative food etc., it has an important influence on the quantity consumed by the grazing animal; Jones (1937), Stapledon et al (1924) and Tribe & Gordon (1950) support this view and conclude that palatability should be assessed in any investigation into nutrient intake.

The quantity of dead herbage eaten by the sheep in winter has not been reported. Stapledon & Davies (1926) and Davies (1925) have, however, discussed the effect of winter 'burn' and the quantity of dead leaves on the palatability of various species. Davies suggested that utilisation of green material is reduced by its relative inaccessibility when dispersed throughout a large amount of dead material. Willoughby (1958) has shown that in a pasture of green and dry components animal production is strongly related to the amount of green material, expressed on a dry weight basis, and only slightly correlated to the total quantity of dry matter present.

Experimental Method.

In order to overcome the difficulties involved in the long range observation of sheep, four sheep were trained to graze when tethered within a few feet of the observer.

The tether and methods used were basically those of Armstrong & Thomas (1952) although in the first series of observations on Cheviot wethers a halter of the type used for show sheep was used.

Two Cheviot wethers in their third winter were used in the first observations in Winter 1958-59. The wethers were taken from the hill and owing to their nervousness were first penned to allow preliminary taming. After about fourteen days the wethers were tethered and observed. At no time, however, would they permit very close observation and they were released after a total of nine hours observations. They were observed for several shorter periods and their grazing habits provided preliminary data on the subject. Cheviot wethers of this age are not ideal subjects for tethering.

In Winter 1959-60 two yearling Scottish Blackface wethers were used. These two were tethered immediately and were easily observed. After four or five days their only reaction to the observer was that they stood up on being approached. The two animals were tethered close enough to share a common water supply and entanglement did not occur. It was, however, necessary to visit them twice daily to prevent kinking of the tethering rope.

In both years the wethers were only observed in winter. Observations were of two types.

1. Observations for a short period on each visit of up to fifteen minutes duration together with observations whenever sampling was taking place within sight of the tethering area.
2. A longer period of watching for one hour upwards on the dates given in Table 19.

TABLE 19

THE DATES AND DURATION OF OBSERVATIONS ON TETHERED HILL WETHERS

Dates	Duration of observation (hrs) A.M.	P.M.
1958 Cheviots		
November 29th	1	2
December 2nd	1	1
December 18th	2	2
1959 Scottish Blackface		
November 15th	1	1
November 21st	2	1
December 9th	1	1
1960		
January 5th	2	-
January 26th	1	2

<u>TABLE 19</u> (Cont.)

	A.M.	P.M.
February 2nd	1	1
February 14th	2	1
February 19th	2	1

The sheep were tethered on a particular community for four days and observations made on the fifth. Four communities were considered:

1. Agrostis tenuis/Festuca ovina dominant.
2. Nardus stricta dominant.
3. Pteridium aquilinium dominant.
4. Deschampsia flexuosa/Festuca ovina dominant.

The sites chosen were those used in the analytical studies and the site locations are therefore shown on Map I, p. 17, and botanical details given in Appendix 3.

General observations were made on the grazing habits of the wethers but particular attention was paid to:

1. Species grazed.
2. The frequency and pattern of biting.
3. Selection or rejection of dead material.

Information obtained by observing the tethered sheep was supported by observations of free-grazing sheep. These were observed on several dates by using binoculars of 10 magnifications which had an engraved scale on the lens.

The estimation of the species grazed, although of less importance than the relative amounts of dead and green consumed, is a useful guide to the nutritional level of the sheep. In order to supplement visual observations, one hundred point quadrats were taken in the grazed area and species recorded for presence and whether grazed. This gave an index of species preference.

Results.

Autumn 1958

Grazing behaviour was observed on only three communities owing to the intractability of the Cheviot wethers.

Agrostis tenuis-Festuca ovina dominant site.

This site was sheltered by a stone wall and well grazed by sheep and cattle. At the time of the observations the herbage was of a uniform height and medium/low percentage of dead material.

Both wethers grazed over all the site in a normal manner, walking and biting on each side of their path, occasionally stopping and grazing more intensely in one small area. Appreciably more grazing occurred at the periphery of the circle allowed them. This was not always on the side furthest away from the experimenter.

Both sheep were selecting individual bites and appeared to be selecting mainly on the greenest clumps. Because of the uniformity of the herbage and its relative lack of dead material individual tillers were not selected.

Results of the point quadrats are given in Table 20 below.

TABLE 20

The number of hits per species in 100 random points and the percentage of grazed points recorded immediately after grazing. (Site Number 5)

Species	Number of hits per hundred points (green tillers only)	Number grazed	Percentage (%) grazed
Agrostis tenuis	85	27	31.8
Festuca ovina	55	19	34.5
Festuca rubra	24	5	20.8
Anthoxanthum odoratum	34	18	52.9
Holcus mollis	29	15	51.7
Nardus stricta	12	6	50.0
Deschampsia flexuosa	5	1	20.0
Cynosurus cristatus	5	4	80.0

Various other grasses and herbs occurred on this site but were not grazed and are omitted from the table.

In this community the Nardus stricta was relatively winter green and for this reason was sought out and grazed. Cynosurus cristatus was present and appears to be highly palatable on this and other sites.

Nardus stricta dominant site (Site No. 8)

This site was an exposed one and the wethers were never happy on it. A very high proportion of the Nardus stricta was dead and no attempt was made by the wethers to eat the dead tillers. Luzula sylvatica and Vaccinium myrtillis were present in some quantity but the co-dominant grass was Deschampsia flexuosa. One of the wethers had access to a small area containing Juncus squarrosus and Deschampsia flexuosa.

The grazing pattern on this site was very different from that noted on the previous site. Both wethers were constantly active, searching among the dead burned herbage for green tillers. Deschampsia flexuosa and Vaccinium myrtillis were well grazed and Luzula sylvatica completely ignored. Although the animal which had access to the Juncus squarrosus area spent some time there, it grazed the associated grasses rather than Juncus squarrosus.

Both the wethers avoided grazing the dead tillers and leaves of Nardus stricta although inevitably some was consumed.

Although this site had a rather limited flora and hence limited selection, point quadrats were recorded and the results given in Table 21.

TABLE 21

The number of hits per species in 100 random points and the percentage of grazed points recorded immediately after grazing. (Site No. 8)

Species.	Number of hits per hundred points (green tillers only)	Number grazed	Percentage grazed
Nardus stricta	35	14	40
Deschampsia flexuosa	70	49	70
Vaccineum myrtillis	28	26	92.9
Luzula sylvatica	30	-	-
Juncus squarrosus	21	4	19

Other grasses and herbs occurred on this site but were not grazed and are omitted from the table.

<u>Pteridium aquilinum dominant site</u> (Site No. 6)

The grass layer on this site was dominated by Agrostis tenuis and canina and Festuca ovina but both Poa pratensis and Holcis mollis were abundant.

The herbage although 4 - 6 cms. high over most of the site was very winter green and only Agrostis tenuis showed any amount of dead material.

Both wethers settled down on the site very quickly and spent less time grazing than on either of the other two sites.

Very little apparent selection occurred and grazing was uniform over the available area. Since there was little dead material on the site it was unnecessary for the wethers to select. It is apparent from the point quadrat results that Agrostis tenuis was neglected, probably because of the larger amount of dead it possesses.

TABLE 22

The number of hits per species in 100 random points and the percentage of grazed points recorded immediately after grazing. (Site No. 6)

Species	Number of hits per hundred points (green tillers only)	Number grazed	Percentage grazed
Agrostis spp.	55	12	21.8
Anthoxanthum odoratum	33	25	75.7
Festuca ovina	50	22	44
Holcus mollis	45	29	64.4
Poa pratensis	67	44	65.6
Carex spp.	20	7	35.0
Cynosurus cristatus	15	11	73.4

Other grasses and herbs occurred on this site but were not grazed and are omitted from the table.

Results 1959 - 1960

The observations in 1959 and 1960 were made on a larger number of sites and for a longer time.

The animals used were yearling Scottish Blackface wethers which were tethered on eight sites, two of each of the main plant communities.

Agrostis tenuis/Festuca ovina dominant sites (Sites 1 and 5)

Both sites used were similar in botanical composition, exposure and vegetation height.

Grazing was in every way similar to that of the Cheviot wethers in the previous year. They did not graze to any apparent pattern but walked and grazed over the entire area alloted to them. The bites taken were small and the vegetation was grazed to within 1 cm. of the ground on average. (Vegetation height before grazing was uniformly 3-4 cm.). Very rarely were individual leaves or tillers selected although in one small area of one site where clumps of Agrostis tenuis, Festuca ovina and Festuca rubra occurred, the wethers were observed to select single green leaves and small groups of leaves.

The actual bite of the wether often tore up the dead leaf base or whole tiller and when this occurred the animal invariably rejected the dead portion.

Point quadrat results are given in Table 23. The figures quoted are the averages of the two sites except where stated.

TABLE 23

The number of hits per species in 100 random points and the percentage of grazed points recorded immediately after grazing. (Site No. 1 & 5)

Species	Number of hits per hundred points (green tillers only)	Number grazed	Percentage grazed
Agrostis tenuis	79	21	26.5
Festuca ovina	59	17	28.8
Festuca rubra	20	7	35
Anthoxanthum odoratum	40	27	67.5
Holcus mollis	35	20	57.1
Cynosurus cristatus	10	4	40
Nardus stricta	19	14	73.6
Poa pratensis	22	15	13.3
Deschampsia caespitosa (One site)	15	2	68.1

Other grasses and herbs occurred on this site but were not grazed and are omitted from the table.

Deschampsia flexuosa/Festuca ovina dominant sites. (Sites 7 & 10)

These sites were not considered in 1959. The vegetation height over most of both sites was only 1 - 2 cm. although both sites had clumps of Nardus stricta within the grazing area of 20 - 25 cms. height.

On both sites the wethers appeared to have difficulty in obtaining sufficient dry matter intake and spent a large part of the observed time grazing.

Selection was limited by the accessibility of the green shoots and lack of vegetation. Any green leaf projecting above the general level was eaten. For this reason the Nardus stricta clumps and their immediate vicinity were grazed more than the rest of the available area. The wethers spent a great deal of time in searching among the dead leaves and leaf bases for green shoots of Nardus stricta and Deschampsia flexuosa. They consistently rejected dead leaf bases when the tearing action of the bite pulled them up and although obviously short of food (and losing weight) they were not observed to graze dead leaves and certainly they never grazed the old shoots of Nardus stricta. It is probable that they took "winter burned" or dead material in the course of their foraging for green shoots.

Point quadrat results show that the wethers grazed most of the species equally. In view of the scarcity of herbage this is an expected result.

TABLE 24

The number of hits per species in 100 random points and the percentage grazed points recorded immediately after grazing. (Site No.7&10)

Species	Number of hits per hundred points (green tillers only)	Number grazed	Percentage grazed
Agrostis tenuis	42	26	61.9
Festuca ovina	65	35	55.4
Deschampsia flexuosa	71	43	60.5
Nardus stricta	33	22	66.6
Carex spp.	37	16	43.2
Luzula campestris	10	2	20.0
Potentilla erecta	21	6	28.5

Other grasses and herbs occurred on this site but were not grazed and are omitted from the table.

Pteridium aquilinum dominant community (Sites No. 2 & 6)

As in 1958 this community provided a great deal of winter green herbage which had been well grazed by the sheep occupying the heft.

The Agrostis tenuis was not so "winter burned" as in 1958 and consequently was grazed at a higher intensity than in the previous year.

The wethers spent less of the observed time grazing on this community than the other three, which is an indication of the relative abundance of available herbage. Individual bites were taken over the whole of the available area and selection was not apparent other than the rejection of dead tillers etc. pulled up when biting. Rejection or selection of a particular area was governed by the lack of dead material rather than the species it contained except in so far as certain species are less winter green than others.

TABLE 25

The number of hits per species in 100 random points and the percentage grazed points recorded immediately after grazing. (Site No.2 & 6)

Species	Number of hits per hundred points. (green tillers only)	Number grazed	Percentage grazed
Agrostis spp.	46	21	45.7
Anthoxanthum odoratum	35	13	37.1
Festuca ovina	49	27	55.2
Holcus mollis	52	29	55.9
Poa pratensis	56	30	53.6
Carex spp.	16	3	18.7
Cynosurus cristatus	17	11	64.8

Other grasses and herbs occurred on this site but were not grazed and are omitted from the table.

Nardus stricta dominant sites (Sites No. 8 and 12)

The Scottish Blackface wethers were as restless on this site as were the Cheviots although conditions over the grazing period were far worse. Both wethers had access to a Juncus squarrosus area on one side and both spent longer grazing this area than had the Cheviots. This was the only difference in grazing behaviour noted.

It was noticed that the wethers rejected dead material torn up by their bites, particularly the tough fibrous leaf bases of Nardus stricta. On many occasions they were seen to have several such dead leaf bases in the back of their mouth which they subsequently rejected. It was difficult to determine whether or not this effect was accidental or a deliberate attempt to sort dead herbage before ingestion.

Individual leaves of both Nardus stricta and the associated grasses were selected and eaten, the wethers often selecting a single green leaf projecting above the tussock and following it down to its source until completely consumed. Most of the grazing took place between and over the tops of Nardus stricta tussocks however and most of their intake was from this area.

Point quadrat results in Table 26 below show some degree of selection although the most important feature affecting the grazing of this community was the great bulk of dead Nardus stricta and the low availability of winter green herbage.

TABLE 26

The number of hits per species in 100 random points and the percentage grazed points recorded immediately after grazing. (Site No. 8 &12)

Species	Number of hits per hundred points (green tillers only)	Number grazed	Percentage grazed.
Nardus stricta	29	13	44.9
Deschampsia flexuosa	63	46	73
Vaccineum myrtillis	20	14	70
Juncus squarrosus	17	12	70.6
Agrostis tenuis	22	9	40.9
Festuca ovina	16	9	56.2

Other grasses and herbs occurred on this site but were not grazed and are omitted from the table.

Observations of untethered sheep.

Although observations recorded on the previous pages give information on the biting method and selectiveness of the sheep concerned, it was necessary to supplement this with observations on normal grazing sheep.

Binoculars were used to determine whether Cheviot ewes had any particular grazing or biting pattern apart from the community preferences noted in Chapter 1. If any such pattern exists it will enable a herbage sample to be collected which will indicate the nutritional level of the ewes.

A total of 24 ewes were observed for varying periods of up to one hour as they moved across different plant communities and the following recorded:

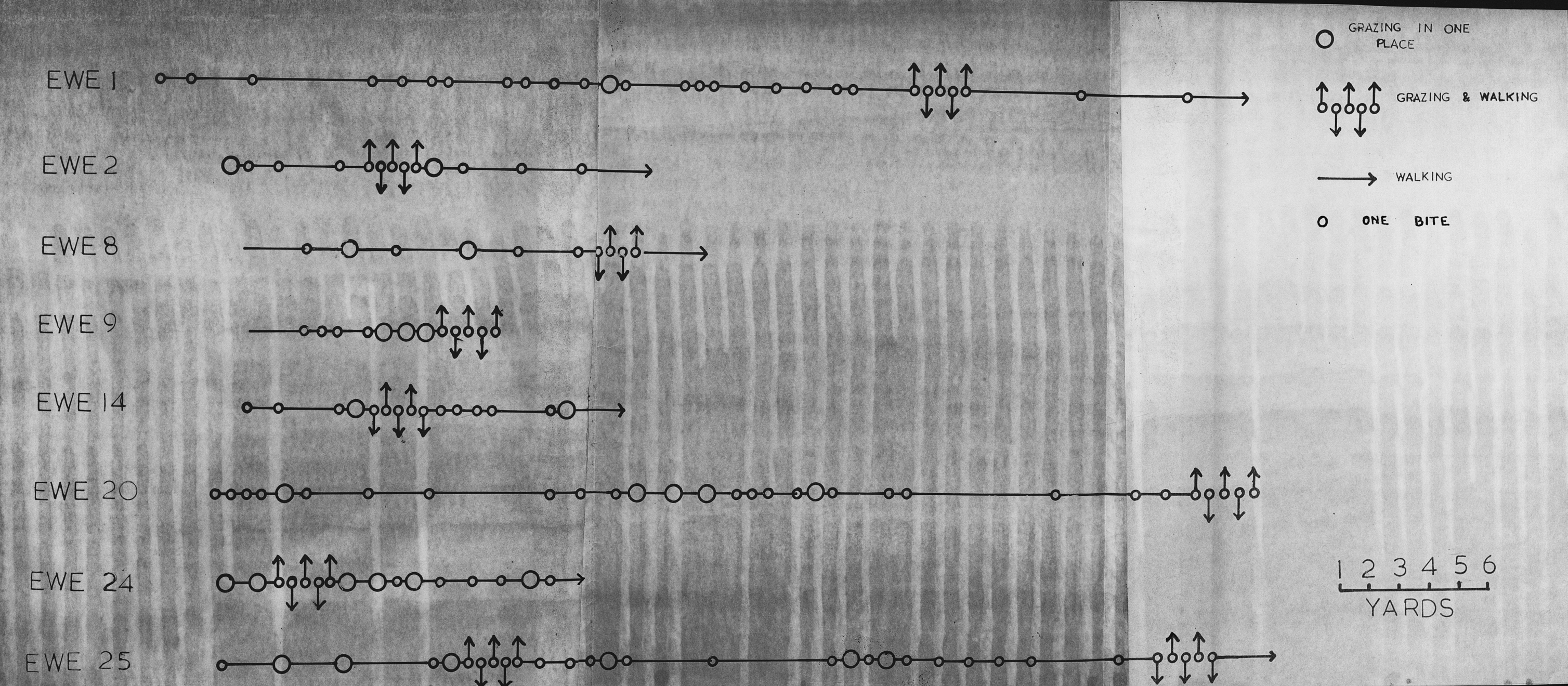
1. General behaviour.
2. Frequency of biting.
3. Distance between bites.
4. Individual variations.

The observations on eight of the ewes are given in Diagram 20, page 129. The distances were estimated in sheep lengths which were then converted into yards by assuming one sheep length to be approximately one yard. It is not suggested that these figures are anything but approximate, the most important factor being the comparisons obtained.

CONCLUSIONS

The observations recorded on previous pages show that different species are grazed at a different intensity. On certain communities, however, the lack of herbage reduces the degree of selection possible if the sheep is to maintain its intake.

Selection appears to be governed by the greenness and availability of the plant. Agrostis tenuis and Festuca ovina show a lower degree of selection than do Holcus mollis and Nardus stricta. Both Agrostis tenuis and Festuca ovina are considerably less winter green than Holcus mollis or Nardus stricta on the communities studied and are therefore rejected


EWE 1
EWE 2
EWE 8
EWE 9
EWE 14
EWE 20
EWE 24
EWE 25
GRAZING IN ONE PLACE
GRAZING & WALKING
WALKING
ONE BITE
1 2 3 4 5 6
YARDS

by the sheep. On sites number 8 and 12 however, the Nardus stricta which contains a lot of dead herbage, is not grazed well and the bulk of the diet is Deschampsia flexuosa. Cynosurus cristatus and Anthoxanthum odoratum are both grazed at a high intensity and are winter green.

The object of the observations was principally to determine the amount of dead herbage consumed by the sheep. This visual method cannot, however, give an accurate estimate of this although useful information was obtained. Sheep attempt to reject dead material, particularly when tough, such as the dead leaves and leaf bases of Nardus stricta. In general both tethered and free sheep were more selective on the Nardus stricta sites and for this reason possibly ingested less dead material on these communities than when grazing the better Agrostis/Festuca communities where each bite took in more herbage. Sheep therefore probably take in least dead herbage when grazing the Pteridium aquilinum dominant community which contains very little dead herbage and most when grazing Agrostis-Festuca dominant communities which contain medium amounts of dead herbage. When grazing Nardus stricta dominant communities sheep appear to ingest less dead herbage because of their greater selectivity.

Both breeds of sheep had similar biting and grazing techniques, the only detectable difference being that of the Scottish Blackface which grazed Juncus squarrosus more than the Cheviots. This may, however, be a reflection of the difference in weather conditions over the grazing period rather than a true difference.

Untethered sheep showed great individual variation in their pattern of grazing but two general patterns emerged. Sheep either grazed whilst walking slowly, the distances between bites varying from below one yard to eight yards or they grazed without moving, searching and selecting within range and then moving some distance (usually over 10 yards) before grazing again. The first method was usually employed when green herbage was relatively plentiful such as on the Agrostis-Festuca sites or Pterdium aquilinum communities and the second when grazing on the Nardus stricta communities. Ewes grazed the different communities in a similar manner as the tethered wethers, although several ewes completely rejected Nardus stricta areas, only commencing grazing immediately they had crossed the community.

In general, therefore, hill sheep select their diet from a wide range of communities, their selection being based on winter greenness and availability. Although certain plant communities are preferred, selection within the community cannot be very great during the winter period. A sampling technique based on greenness and availability should therefore give an approximate value to the nutrient content of the grazing herbage. This technique is used in Chapter 5.

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CHAPTER 5

An estimation of the diet of hill ewes using a sampling method.

Introduction

Owing to the selection practised by the sheep, the chemical analysis of herbage cut in the normal way, does not give a reliable indication of the nutrients ingested by the sheep. Although the digestibility of the nutrients is another very important source of error in determining the nutritional value of winter herbage by a cutting and analytical technique, the differential selectivity is of great importance. An attempt was, therefore, made in Chapter 4 to investigate the degree of selection practised and the factors affecting it, in order to develop a technique of herbage sampling which approximates to the diet of hill sheep. This method was only used in winter when the degree of selection is low. The technique was basically an attempt to fix the upper and lower limits of the diet by imitating the grazing sheep as far as possible.

Experimental method.

In order to assess the value of each of the plant communities to the sheep, sampling was carried out on several. In the spring of 1950 three types of community were considered on four different hefts. In autumn 1959 and spring 1960 four types of community were sampled on three hefts.

Six inch quadrats were distributed over the sites chosen (see Appendix 3). and the sampling carried out within them. One pinch sample was selected within each quadrat, the basis for selection being greenness and accessibility (i.e. similar criteria to those believed used by sheep). Within the same quadrat a random pinch sample of similar size was taken. The samples were cut by scissors and bulked separately to give the upper and lower limits of the diet.

The number of quadrats and samples were approximately the same on each community, as approximately one hundred grams of herbage were collected. The quadrats were distributed over the communities in two ways. On the Pteridium aquilinum, Agrostis-Festuca and Deschampsia flexuosa dominant communities the quadrats were randomly distributed using random number co-ordinates. On the Nardus stricta community, however, the quadrats were grouped regularly around random points. The different sampling methods reflect the different grazing techniques adopted on these communities. When quadrats fell on mainly dead tussocks of Nardus stricta or other species, green leaves were sought and sampled as sheep had been observed to do. The bulk samples obtained in this way were stored in polythene bags, dried and chemically analysed as in Chapter 3.

Results

The complete results are given in Appendix 6. Tables 27 to 30 give the mean of three or four hefts (four in autumn and spring 1959) together with the mean difference between selected and random samples.

The tables show that it is possible to fix the limits of the diet with reasonable accuracy. The maximum difference between the upper and lower limits is approximately 14% and occurs in the Crude protein figures, the lowest is 4% in the Nitrogen free extract (N.F.E.). Since a 14% difference represents only 1.4% crude protein it can be seen that these limits are usefully close.

The nutrient content of the samples from the four communities reflect the nutrient content of the dominant grass species. For example the Pteridium aquilinum dominant community shows the highest nutritional value and Nardus stricta the lowest. The dominant grasses in these communities are Holcus mollis and Nardus stricta, pure samples of which have the highest and lowest nutrient content respectively. As may be expected, the nutritional value of the pinch samples (selected) is lower than that of the pure species in almost every case. This is a measure of the amount of dead herbage contained in the pinch sample. The fact that the selected pinch sample also contains species other than the dominant will affect the nutrient content.

TABLE 27

Crude protein content of pinch samples (mean of three hefts).

COMMUNITY

Date	Agrostis festuca		Pteridium aquilinum		Deschampsia flexuosa		Nardus stricta	
	Selected	Random	Selected	Random	Selected	Random	Selected	Random
Autumn								
29/10/59	10.4	6.6	11.3	10.9	9.0	8.6	8.3	6.4
2/12/59	9.2	8.4	11.8	11.3	9.3	8.5	8.4	7.5
Spring								
3/2/60	10.3	9.8	11.1	10.6	9.7	9.4	8.3	7.0
3/3/59) 1/3/60) mean	10.6	9.4	13.0	11.6	11.8	9.9	8.7*	7.4*
2/4/59) 4/4/60) mean	16.0	14.5	18.6	15.6	14.1	12.4	13.1*	11.2*

* 1960 results only.

TABLE 28

Crude fibre content of pinch samples (mean of three hefts).

	COMMUNITY							
	Agrostis festuca		Pteridium aquilinum		Deschampsia flexuosa		Nardus stricta	
Date	Selected	Random	Selected	Random	Selected	Random	Selected	Random
Autumn								
29/10/59	29.2	29.6	27.7	29.0	25.7	30.6	31.1	35.4
2/12/59	33.6	31.9	34.6	27.7	30.0	28.7	25.5	31.3
Spring								
3/2/60	36.5	38.0	31.9	33.4	33.6	38.1	35.4	37.2
3/3/59) 1/3/60) mean	29.4	33.8	30.3	30.7	31.2	33.8	34.5*	35.5*
2/4/59) 4/4/60) mean	25.3	27.8	23.9	26.7	27.5	28.9	30.1*	32.0*

* 1960 result only.

TABLE 29

Ash content of pinch samples (mean of three hefts).

	COMMUNITY							
	Agrostis festuca		Pteridium aquilinum		Deschampsia flexuosa		Nardus stricta	
Date	Selected	Random	Selected	Random	Selected	Random	Selected	Random
Autumn								
29/10/59	6.0	5.4	6.1	5.9	4.1	4.1	5.9	6.5
2/12/59	6.0	5.2	5.6	5.9	3.8	4.1	6.5	5.4
Spring								
3/2/60	5.4	5.4	5.8	5.8	4.0	4.0	6.4	6.2
3/3/59) 1/3/60) mean	6.0	5.9	6.1	6.5	4.8	5.1	5.9*	6.4*
2/4/59) 4/4/60) mean	6.3	5.8	6.0	5.6	4.3	4.7	5.3*	5.1*

* 1960 results only.

TABLE 30

Ether extract content of pinch samples (mean of three hefts).

	COMMUNITY							
	Agrostis festuca		Pteridium aquilinum		Deschampsia flexuosa		Nardus stricta	
Date	Selected	Random	Selected	Random	Selected	Random	Selected	Random
Autumn								
29/10/59	2.4	2.2	2.4	2.4	2.5	2.0	2.4	1.8
2/12/59	2.7	2.3	2.0	2.0	2.8	3.0	2.4	2.1
Spring								
3/2/60	2.2	2.1	1.5	2.0	2.4	2.3	2.1	2.4
3/3/59) 1/3/60) mean	2.2	2.1	2.0	2.2	2.4	2.3	1.9*	2.1*
2/4/50) 4/4/60) mean	2.3	2.1	2.1	2.0	2.5	2.2	2.2*	2.0*

* 1960 results only.

<u>Conclusions</u>

It is unlikely that sheep consciously select dead material or patches containing large amounts of dead (see Chapter 4) and, therefore, a random pinch sample may be taken to represent the lower limit of nutrient intake. The pinch sample was selected using the same criteria as the sheep as far as our knowledge of these criteria allows. It is, therefore, suggested that the lower level is the minimum possible, but the upper level may need modification as knowledge of the factors influencing selection improves.

The figures in Tables 27 to 30 also show the possible differences in the nutritive level of families of sheep grazing different communities. The difference in crude protein content of the selected samples varies between 18.0% (Pteridium aquilinum dominant) and 13.1% (Nardus stricta dominant). This difference is repeated in the other constituents. Although the level of protein may be perfectly adequate even on the Nardus stricta dominant sites (no reliable figures are available on the nutritive requirements of hill sheep) it seems possible that the differences noted may have some effect on the performance of the ewes. The inadequacy of the diet on better quality hill grassland would therefore appear to be quantitative rather than qualitative although the energy levels may be limiting under certain conditions.

The conclusions must be that supplementary winter feeding of hill ewes should be confined to high energy, high mineral content in a palatable bulky food. Good hay should provide the necessary requirements although for practical reasons concentrates are often fed.

CONCLUSIONS

The basic problem of hill farming is the efficient utilisation of a semi-natural environment. The animal most frequently used for this purpose is the sheep and it is with sheep and their utilisation of hill pastures that this thesis has been concerned. The heft is a complex ecosystem of several sward types grazed at different intensities and producing varying amounts of animal nutrients. The factors governing the grazing intensity and productivity of various communities are not simply those inherent in the community although these are of some importance. Social factors resulting in a non-random distribution of the sheep over the available pasture have been demonstrated and the importance of the home range of the ewes in determining the home range of the lamb shown. This obviously has a considerable effect on the utilisation of the different communities particularly since up to the present time no account has been taken of the home range of a ewe and lamb when selecting replacement breeding stock. This has resulted in the selection of lambs from better environments rather than lambs of possibly superior breeding merit. The extent of the environmental difference cannot be accurately determined but sufficient has been produced to show that it is likely to be a very potent source and possibly the most important source of variation in the flock.

The chief conclusion of this thesis must be that without prior consideration of the complex factors governing the grazing of hill pastures, improvement is blind and may only be of short term value. The increased productivity of a hill flock and of a hill sward is essentially an ecological problem and should be treated so. The preliminary results in this thesis are an attempt at a solution of some of the ecological problems involved.

APPENDIX 1.

Monthly Climatological Observations at Sourhope for the period August 1958 to September 1960.

These observations, taken at an altitude of 900 ft. O.D. close to the farm buildings (Map 1), give an approximation to conditions on the study area.

Month & Year.	Rainfall (inches)	Mean Temp. °F.	Frost (days in month) Air	Frost (days in month) Grnd.	Bright sunshine (hrs)
1958					
September	2.63	55.9	0	0	5.28
October	1.94	48.9	0	3	3.31
November	0.63	41.7	10	16	1.96
December	5.22	37.6	12	21	1.74
1959					
January	2.26	31.5	23	26	3.05
February	0.45	38.7	16	11	2.68
March	1.07	41.9	3	14	3.24
April	2.47	44.6	4	10	4.78
May	0.74	50.4	3	3	7.04
June	2.55	55.3	0	0	6.16
July	1.95	58.5	0	1	5.66

Month & Year.	Rainfall (inches)	Mean Temp. °F	Frost (days in month) Air	Grnd.	Bright sunshine (hrs)
1959 (Cont.)					
August	0.78	59.7	0	0	5.8
September	1.02	56.1	0	1	5.64
October	1.65	52.4	1	2	4.34
November	7.29	42.7	5	9	1.79
December	6.13	38.7	6	16	0.65
1960					
January	4.52	35.7	23	21	1.39
February	3.01	34.6	19	21	3.06
March	1.6	39.1	8	14	2.63
April	1.64	45.5	4	11	5.06
May	1.93	50.9	1	1	6.42
June	1.15	57.2	0	0	7.51
July	3.48	55.4	0	1	4.16
August	4.81	55.1	0	1	4.71
September	2.53	52.2	0	1	4.04

APPENDIX 2.

The species lists given on the following pages are typical of these communities on the Gairs heft, although no attempt was made to characterise all the area of a particular community on the heft. The list of vascular plants is as complete as possible although the rarer species in a particular community may well have been omitted. The mosses, liverworts and lichens given, represent the commonest and most conspicuous members of these orders and no attempt was made to give a complete list.

Cover/abundance is given on Domin's scale (Poore, 1955).

NARDETUM

Species	Domin scale.	Species	Domin scale
Vaccinium myrtillus	3	Luzula multiflora	3
Agrostis canina	5	Luzula sylvatica	3
Agrostis tenuis	3	Galium hercynicum	4
Anthoxanthum odoratum	4	Potentilla erecta	4
Deschampsia flexuosa	7	Hylocomium splendens	3
Festuca ovina	7	Hypnum cupressiforme	5
Molinia caerulea	2	Rhytidiadelphus squarrosus	4
Nardus stricta	9	Lophocolea bidentata	2
Carex binervis	2		
Carex panicea	3		
Juncus squarrosus	3		

AGROSTIS-FESTUCA grassland.

Species	Domin scale	Species	Domin scale
Agrostis canina	3	Achillea millefolium	3
Agrostis tenuis	7	Campanula rotundifolia	2
Anthoxanthum odoratum	4	Galium hercyicum	3
Deschampsia caespitosa	2	Lotus corniculatus	2
Festuca ovina	8	Potentilla erecta	3
Festuca rubra	5	Rumex acetosa	3
Helictotrichon pubescens	3	Trifolium repens	4
Holcus lanatus	4	Veronica chamaedrys	3
Nardus stricta	2	Hylocomium splendens	5
Poa pratensis	2	Mnium undulatum	2
Carex caryophyllea	3	Pseudoscleropodium purum	4
Carex pilulifera	2	Rhytidiadelphus squarrosus	5
Luzula campestris	3	Thuidium tamariscinum	2

PTERIDIETUM

Species	Domin scale	Species	Domin scale
Pteridium aquilinum	8	Carex caryophyllea	2
Agrostis canina	6	Campanula rotundifolia	1
Agrostis tenuis	6	Galium hercynicum	7
Anthoxanthum odoratum	4	Lathyrus montanus	1
Festuca ovina	8	Potentilla erecta	5
Holcus mollis	6	Viola spp.	3
Poa pratensis	7	Hylocomium splendens	3
Poa trivialis	2	Hypnum cupressiforme	4
Luzula campestris	2	Pleurozium schreberi	4
Carex pilulifera	3	Rhytidiadelphus squarrosus	4

MOLINIETUM

Species	Domin scale	Species	Domin scale
Erica tetralix	2	Potentilla erecta	3
Myrica gale	3	Sphagnum spp.	4
Agrostis canina	2	Hylocomium splendens	2
Deschampsia flexuosa	1	Hypnum cupressiforme	2
Festuca ovina	2	Rhytidiadelphus squarrosus.	2
Molinia caerulea	8		

Other species occur such as Narthecium ossifragum
Calluna vulgaris
Juncus squarrosus

but usually only in small amount or close to the boundary with other communities.

ERIOPHORETUM

Species	Domin scale	Species	Domin scale
Calluna vulgaris	2	Eriophorum vaginatum	8
Empetrum nigrum	4	Juncus squarrosus	4
Erica tetralix	2	Hylocomium splendens	4
Vaccinium myrtillus	2	Pleurozium schreberi	3
Deschampsia flexuosa	1	Sphagnum spp.	5

MOLINIA/JUNCUS/HEATHER community.

Species	Domin scale	Species	Domin scale
Calluna vulgaris	7	Vaccinium myrtillis	1
Erica tetralix	5	Deschampsia flexuosa	1
Erica cinerea	5	Molinia caerulea	6
Myrica gale	1	Eriophorum vaginatum	2

MOLINIA/JUNCUS/HEATHER community (Cont.)

Species	Domin scale	Species	Domin scale
Trichophorum caespitosum	4	Hylocomium splendens	1
Juncus squarrosus	5	Hypnum cupressiforme	3
Potentilla erecta	3	Sphagnum spp.	6

JUNCETUM

Species	Domin scale	Species	Domin scale
Agrostis canina	4	Galium hercynicum	2
Agrostis tenuis	3	Potentilla erecta	3
Anthoxanthum odoratum	2	Polytrich um commune	5
Holcus mollis	3	Hylocomium splendens	3
Carex nigra	3	Rhytidiadelphus squarr-osus	3
Juncus effusus	8	Sphagnum spp.	7

APPENDIX 3

The botanical details given in this appendix are of sites used in Chapters 3, 4 and 5. Cover/abundance figures on the Domin scale (Poore, 1955) were estimated on the sites (initially point quadrats were used to check the accuracy of the estimates).

Site 1 - Park Law

Altitude	900 ft. O.D.
Aspect	230°
Slope	10°
Cover	/80/30
Herbage length	6 - 8"

Sheep and cattle grazed

Species	Domin scale	Species	Domin scale
Agrostis canina	3	Achillea millefolium	4
Agrostis tenuis	8	Campanula rotundifolia	2
Anthoxanthum odoratum	4	Galium hercynicum	4
Deschampsia caespitosa	Clumps within site	Rumex acetosa	1
		Viola sp.	1
Festuca ovina	9	Lotus corniculatus	2
Festuca rubra	5	Rumex acetosa	3
Nardus stricta	Clumps within site	Thymus drucei	2
Poa pratensis	3	Hylocomium splendens	3
Holcus lanatus	3	Hypnum cupressiforme	2
Carex caryophyllea	3	Pseudoscleropodium purum	3
Luzula campestris	3	Rhytidiadelphus squarrosus	4

Site 2 - Park Law.

Altitude	850 ft. O.D.
Aspect	200°
Slope	10°
Cover	80/100/30
Herbage length	4 - 6" (grass layer)
Sheep grazed	

Species	Domin scale	Species	Domin scale
Pteridium aquilinum	8	Conopodium majus	1
Agrostis canina	5	Galium hercynicum	4
Agrostis tenuis	8	Lathyrus montanus	1
Anthoxanthum odoratum	5	Potentilla erecta	4
Deschampsia caespitosa	4	Rumex acetosa	4
Festuca ovina	7	Stellaria graminea	1
Festuca rubra	5	Trifolium repens	1
Holcus mollis	5	Atrichium undulatum	1
Poa pratensis	4	Eurynchium praelongum	3
Luzula campestris	3	Hylocomium splendens	2
Carex pilulifera	2	Hypnum cupressiforme	2
Cirsium arvense	1	Mnium undulatum	1
Cirsium palustre	1	Pseudoscleropodium purum	5
		Rhytidiadelphus squarrosus	5

Site 3 - Park Law

Altitude	1000 ft. O.D.
Aspect	140°
Slope	15°
Cover	/90/50
Herbage length	1 - 2"
Sheep grazed	

Species	Domin scale	Species	Domin scale
Vaccinium myrtillus	1	Galium hercynicum	5
Agrostis tenuis	4	Potentilla erecta	4
Anthoxanthum odoratum	2	Rumex acetosa	2
Deschampsia flexuosa	2	Dicranum scaparium	3
Festuca ovina	7	Hylocomium splendens	4
Nardus stricta	4	Hypnum cupressiforme	4
Carex caryophyllea	1	Pleurozium schreberi	5
Carex pilulifera	2	Rhytidiadelphus squarrosus	4
Luzula campestris	4		

Site 4 - Park Law

Altitude	900 ft. O.D.
Aspect	20°
Slope	-
Cover	/100/40
Herbage length	6 - 8"
Sheep grazed	

Species	Domin scale	Species	Domin scale
Calluna vulgaris	1	Luzula multiflora	3
Vaccinium myrtillus	3	Luzula sylvatica	3
Agrostis canina	3	Galium hercynicum	4
Anthoxanthum odoratum	3	Potentilla erecta	4
Deschampsia flexuosa	6	Hylocomium splendens	3
Festuca ovina	7	Hypnum cupressiforme	5
Molinia caerulea	2	Plagiothecium undulatum	3
Nardus stricta	8	Pleurozium schreberi	6
Carex panicea	3	Rhytidiadelphus squarrosus	4
Carex binervis	2	Lophocolea bidentata	2
Juncus squarrosus	3		

Site 5 - Hairney Law

Altitude	750 ft. O.D.
Aspect	45°
Slope	15°
Cover	/95/40
Herbage length	3 - 4"

Cattle and sheep grazed.

Species	Domin scale	Species	Domin scale
Agrostis canina	5	Festuca rubra	4
Agrostis tenuis	8	Holcus mollis	3
Anthoxanthum odoratum	4	Nardus stricta	2
Deschampsia flexuosa	2	Carex pilulifera	2
Festuca ovina	8	Luzula campestris	4

Site 5 - Hairney Law (Continued)

Species	Domin scale	Species	Domin scale
Achillea millefolium	3	Hylocomium splendens	4
Galium hercynicum	5	Hypnum cupressiforme	2
Potentilla erecta	5	Polytrichum commune	2
Rumex acetosa	2	Pleurozium schreberi	4
Thymus drucei	5	Rhytidiadelphus squarrosus	5

Site 6 - Hairney Law

Altitude 750 ft. O.D.

Aspect 50°

Slope 15°

Cover 70/85/30

Herbage length 4 - 6" (grass layer)

Sheep and cattle grazed.

Species	Domin scale	Species	Domin scale
Pteridium aquilinum	7	Carex pilulifera	3
Agrostis canina	3	Achillea millefolium	2
Agrostis tenuis	7	Anemone nemorosa	1
Anthoxanthum odoratum	5	Campanula rotundifolia	1
Cynosurus cristatus	2	Galium hercynicum	6
Deschampsia flexuosa	1	Lathyrus pratensis	1
Festuca ovina	8	Potentilla erecta	5
Holcus mollis	6	Ranunculus repens	2
Poa pratensis	7	Viola sp.	3
Poa trivialis	2	Hylocomium splendens	3
Luzula campestris	2	Pseudoscleropodium purum	4
		Rhytidiadelphus squarrosus	5

Site 7 - Hairney Law

Altitude 890 ft O.D.

Aspect 50°

Slope 30°

Cover /70/10

Herbage length

Sheep and cattle grazed.

Species	Domin scale	Species	Domin scale
Agrostis tenuis	5	Luzula campestris	2
Anthoxanthum odoratum	1	Galium hercynicum	4
Deschampsia flexuosa	8	Potentilla erecta	5
Festuca ovina	6	Dicranum scoparium	3
Nardus stricta	2	Hylocomium splendens	3
Carex caryophyllea	2	Hypnum cupressiforme	4
Carex binervis	3	Pleurozium schreberi	5
Carex pilulifera	2	Rhytidiadelphus squarrosus	5

Site 8 - Hairney Law

Altitude 950 ft. O.D.

Aspect 50°

Slope 10°

Cover 180/40

Herbage length

Sheep grazed

Site 8 - Hairney Law (Continued)

Species	Domin scale	Species	Domin scale
Vaccinium myrtillus	4	Luzula campestris	3
Agrostis canina	5	Galium hercynicum	4
Agrostis tenuis	4	Lathyrus montanus	2
Anthoxanthum odoratum	3	Potentilla erecta	4
Deschampsia flexuosa	6	Rumex acetosa	2
Festuca ovina	7	Thymus drucei	1
Molinia caerulea	1	Campylopus flexuosa	1
Nardus stricta	8	Dicranum scoparium	2
Poa pratensis	3	Hylocomium splendens	4
Carex binervis	2	Hypnum cupressiforme	4
Carex caryophyllea	2	Pleurozium schreberi	5
Carex pilulifera	2	Rhytidiadelphus squarrosus	5
Juncus squarrosus	2	Lophocolea bidentata	2

Site 9 - Fassett

Altitude	800 ft. O.D.
Aspect	290°
Slope	18°
Cover	-/100/70
Herbage length	6 - 12"
Sheep grazed	

Species	Domin scale	Species	Domin scale
Agrostis canina	7	Veronica serpyllifolia	1
Agrostis tenuis	7	Vicia sepium	1
Anthoxanthum odoratum	5	Conopodium majus	3
Deschampsia caespitosa	4	Rumex acetosa	2
Deschampsia flexuosa	3	Lathyrus montanus	3
Festuca ovina	9	Potentilla erecta	4
Festuca rubra	4	Campanula rotundifolia	2
Holcus lanatus	4	Lathyrus pratensis	3
Holcus mollis	4	Galium hercynicum	4
Helictotrichon pubescens	3	Ranunculus acris	2
Helictotrichon pratense	3	Viola riviniana	2
Nardus stricta	5	Hylocomium splendens	5
Poa pratensis	3	Hypnum cupressiforme	5
Luzula campestris	3	Mnium undulatum	1
Carex panicea	2	Pleurozium schreberi	6
Carex pilulifera	3	Polytrichum urnigerum	3
Juncus effusus	1	Rhytidiadelphus squarrosus	4
Cirsium palustre	1		

Site 10 - Fassett

Altitude	950 ft. O.D.
Aspect	160°
Slope	30°
Cover	/90/60
Herbage length	2 - 3"

Sheep and cattle grazed.

Site 10 - Fassett (Continued)

Species	Domin scale	Species	Domin scale
Vaccinium myrtillus	1	Hieracium pilosella	2
Agrostis canina	4	Leontodon autumnalis	2
Agrostis tenuis	7	Potentilla erecta	4
Anthoxanthum odoratum	4	Rumex acetosa	4
Deschampsia flexuosa	7	Viola canina	4
Festuca ovina	8	Thymus drucei	5
Nardus stricta	Clumps	Antennaria dioica	2
Sieglingia decumbens	2	Dicranum scoparium	1
Luzula campestris	2	Pleurozium schreberi	1
Carex pilulifera	4	Polytrichum juniperinum	3
Campanula rotundifolia	3	Campylopus flexuosa	3
Galium hercynicum	5		

Site 11 - Fassett

Altitude	900 ft. O.D.
Aspect	200°
Slope	10°
Cover	90/80/30
Herbage length	2 - 4" (grass layer)

Sheep grazed.

Species	Domin scale	Species	Domin scale
Pteridium aquilinum	8	Festuca ovina	7
Agrostis canina	5	Festuca rubra	3
Agrostis tenuis	7	Holcus mollis	5
Anthoxanthum odoratum	4	Holcus lanatus	3

Site 11 - Fassett (Continued)

Species	Domin scale	Species	Domin scale
Poa pratensis	4	Potentilla erecta	5
Poa trivialis	1	Hylocomium splendens	2
Luzula campestris	3	Hypnum cupressiforme	3
Carex pilulifera	2	Mnium undulatum	2
Galium hercynicum	4	Rhytidiadelphus squarrosus	5
Lathyrus montanus	1		

Site 12 - Fassett

Altitude	1100 ft. O.D.
Aspect	220°
Slope	15°
Cover	-/80/40
Herbage length	8 - 12"

Sheep and cattle grazed.

Species	Domin scale	Species	Domin scale
Agrostis ténuis	3	Luzula pilosa	2
Anthoxanthum odoratum	4	Galium hercynicum	4
Deschampsia flexuosa	7	Potentilla erecta	4
Festuca ovina	6	Oxalis acetosella	1
Molinia caerulea	1	Dicranum scoparium	2
Nardus stricta	9	Hylocomium splendens	3
Carex binervis	2	Hypnum cupressiforme	4
Carex panicea	2	Pleurozium schreberi	6
Juncus squarrosus	3	Rhytidiadelphus squarrosus	4
Luzula multiflora	2		

Site 13 - Gairs

Altitude	840 ft. O.D.
Aspect	225°
Slope	10°
Cover	10/3
Herbage length	2 - 8"
Sheep grazed.	

Species	Domin scale	Species	Domin scale
Agrostis canina	2	Carex panicea	4
Agrostis tenuis	8	Juncus effusus	3
Anthoxanthum odoratum	5	Cerastium vulgatum	1
Cynosurus cristatus	3	Cirsium arvense	2
Deschampsia caespitosa	5	Cirsium palustre	3
Festuca ovina	6	Galium uliginosum	1
Festuca rubra	7	Lathyrus pratensis	3
Holcus lanatus	5	Lotus corniculatus	2
Helictotrichon pubescens	5	Potentilla erecta	4
Nardus stricta	4	Primula vulgaris	2
Poa pratensis	6	Ranunculus acris	4
Poa trivialis	1	Ranunculus ficaria	4
Trisetum flavescens	2	Ranunculus repens	2
Cardamine pratensis	1	Rumex acetosa	2
Carex caryophyllea	2	Stellaria graminia	2
Carex flacca	3	Trifolium repens	4
Luzula campestris	4	Veronica chamaedrys	1
Juncus articulatus	1	Vicia sepium	2
Carex nigra	3	Acrocladium cuspidatum	2
Carex ovalis	3	Hylocomium spendens	3
Mnium andulatum	2	Pleurozium schreberi	1
		Rhytidiadelphus squarrosus	6

Site 14 - Gairs

Altitude 900 ft. D.D.

Aspect 240°

Slope -

Cover -/80/60

Herbage length 8 - 10"

Sheep grazed.

Species	Domin scale	Species	Domin scale
Calluna vulgaris	2	Luzula sylvatica	3
Vaccinium myrtillus	2	Trichopherum caespitosum	1
Agrostis canina	5	Galium hercynicum	4
Agrostis tenuis	5	Potentilla erecta	4
Deschampsia flexuosa	7	Hylocomium spendens	3
Festuca ovina	6	Hypnum cupressiforme	5
Nardus stricta	9	Plagiothecium undulatum	3
Molinia caerulea	2	Pleurozium schreberi	6
Carex nigra	2	Polytrichum commune	2
Carex panicea	3	Rhytidiadelphus squarr-osus	4
Carex pilulifera	2	Lophocolea bidentata	2
Juncus squarrosus	3		

Site 15 - Gairs

Altitude 950 ft. O.D.

Aspect 270°

Slope -

Cover /70/50

Herbage length 1 - 2"

Site 15 - Gairs (Continued)

Species	Domin scale	Species	Domin scale
Agrostis canina	4	Achillea millefolium	2
Agrostis tenuis	4	Campanula rotundifolia	2
Anthoxanthum odoratum	3	Galium hercynicum	5
Deschampsia flexuosa	7	Potentilla erecta	4
Festuca ovina	8	Dictranum scoparium	3
Holcus mollis	2	Hylocomium splendens	4
Nardus stricta	4	Hypnum cupressiforme	3
Carex caryophyllea	1	Pleurozomium schreberi	5
Carex pilulifera	2	Polytrichum juniperimum	3
Luzula campestris	4	Rhytidiadelphus squarr-osus	4

Site 16 - Gairs

Altitude	1000 ft. O.D.
Aspect	270°
Slope	10°
Cover	70/80/40
Herbage length	
Sheep grazed	

Species	Domin scale	Species	Domin scale
Pteridium aquilinum	8	Deschampsia caespitosa	clumps
Agrostis canina	4	Deschampsia flexuosa	4
Agrostis tenuis	5	Festuca ovina	7
Anthoxanthum odoratum	4	Festuca rubra	3

Site 16 - Gairs (Continued)

Species	Domin scale	Species	Domin scale
Holcus mollis	8	Rumex acetosa	3
Poa pratensis	5	Hylocomium splendens	4
Carex caryophyllea	2	Hynum cupressiforme	3
Carex pilulifera	2	Pleurozium schreberi	4
Luzula campestris	4	Pseudosleropodium purum	5
Galium hercynicum	4	Rhytidiadelphus squarr-osus	5
Potentilla erecta	3		

APPENDIX 4

Monthly analyses over two seasons, of eight important hill grass species.

Key to Species Names.

At ... Agrostis tenuis

Ao ... Anthoxanthum odoratum

Dc ... Deschampsia caespitosa

Df ... Deschampsia flexuosa

Fo ... Festuca ovina

Fr ... Festuca rubra

Ho ... Holcus mollis

Ns ... Nardus stricta

% OIL

Species / Date	25/9/58	22/10/58	20/11/58	23/12/58	25/1/59	26/2/59	24/3/59	27/4/59	27/5/59	27/6/59	28/7/59
At.	1.9	1.8	1.7	2.0	2.0	1.4	2.0	2.7	3.0	2.1	2.1
Ao.	1.7	1.7	1.7	2.8	1.9	1.3	2.4	3.0	1.8	1.8	1.7
Dc.	1.8	2.6	1.4	1.6	1.4	1.3	2.0	2.2	2.4	1.7	1.8
Df.	2.7	2.8	2.9	2.7	2.8	2.4	3.2	3.0	2.5	2.2	2.9
Fo.	2.8	2.8	2.8	2.3	2.5	2.9	2.6	2.3	2.2	2.6	2.8
Fr.	2.2	2.3	2.7	2.3	2.2	2.2	2.4	2.7	2.6	2.1	2.0
Ho.	2.2	2.3	2.2	2.5	2.4	2.5	2.7	3.4	3.5	2.0	2.5
Ns.	0.8	0.6	0.5	0.8	0.8	1.0	1.2	1.2	2.3	1.3	1.2

Species / Date	15/8/59	28/9/59	28/10/59	9/11/59	19/12/59	26/1/60	10/2/60	15/3/60	28/4/60	6/5/60	25/6/60	28/7/60	11/8/60
At.	2.0	1.8	2.1	2.0	2.8	3.0	3.0	2.6	2.6	2.5	2.0	1.7	1.8
Ao.	1.8	1.9	2.5	2.8	1.7	1.9	2.6	2.1	2.0	2.0	1.6	1.8	1.9
Dc.	1.6	1.7	1.9	2.7	2.0	2.3	2.3	2.2	1.9	1.7	1.5	1.6	1.4
Df.	3.4	3.7	2.8	2.8	3.9	3.7	3.2	3.1	3.0	2.7	2.1	1.9	2.2
Fo.	3.1	2.6	2.5	2.4	2.3	3.4	3.2	2.8	2.9	2.4	2.2	2.2	2.0
Fr.	2.0	1.9	2.6	3.2	3.3	3.2	3.1	3.2	2.9	2.6	1.8	1.7	1.6
Ho.	2.3	1.9	2.3	2.7	2.8	3.1	3.3	3.0	2.6	2.5	2.4	2.0	1.9
Ns.	1.4	1.0	1.5	1.7	1.1	1.3	0.9	1.0	0.8	0.9	0.8	0.9	1.0

% CRUDE PROTEIN

Species / Date	25/9/58	22/10/58	20/11/58	23/12/58	25/1/59	26/2/59	24/3/59	27/4/59	27/5/59	27/6/59	28/7/59
At.	11.4	11.5	11.2	12.7	12.5	12.8	14.0	19.3	13.4	11.6	10.2
Ao.	11.7	10.8	10.2	12.1	12.3	12.7	16.8	19.6	10.7	7.5	9.5
Dc.	8.6	8.6	8.4	12.1	12.2	12.7	13.4	15.8	12.6	7.6	7.8
Df.	12.7	12.9	15.7	14.7	14.0	14.9	16.0	12.0	10.6	9.0	9.5
Fo.	10.3	10.7	11.1	11.4	12.0	12.9	13.3	12.0	8.8	9.3	11.4
Fr.	10.8	11.0	11.2	14.2	12.0	11.7	13.5	15.5	12.4	8.2	9.8
Ho.	13.4	14.0	15.5	15.6	16.4	17.5	17.9	19.9	13.5	12.7	9.8
Ns.	10.3	10.5	10.8	11.4	12.0	16.5	17.0	15.4	13.3	9.6	9.8

Species / Date	15/8/59	28/9/59	28/10/59	9/11/59	19/12/59	26/1/60	10/2/60	15/3/60	28/4/60	6/5/60	25/6/60	28/7/60	11/8/60
At.	9.0	10.0	10.0	12.6	16.6	15.5	17.6	17.5	18.1	20.0	11.0	11.5	10.6
Ao.	10.3	11.8	13.1	14.4	19.0	12.5	13.6	17.0	21.4	18.7	10.4	10.0	9.7
Dc.	7.6	8.0	10.9	10.9	10.4	12.1	12.1	15.9	17.5	21.4	13.4	9.5	9.7
Df.	8.5	9.7	10.1	10.3	15.0	14.8	15.8	18.6	24.1	17.8	12.5	10.6	12.0
Fo.	11.0	10.0	10.5	9.6	9.2	10.1	14.0	15.0	16.1	14.9	9.5	10.0	10.3
Fr.	10.0	11.7	12.0	15.0	20.5	20.2	20.0	22.5	24.9	16.5	14.0	11.2	10.9
Ho.	8.0	8.7	12.0	17.9	20.6	22.2	2310	25.2	15.3	20.1	16.5	14.6	-
Ns.	9.6	9.3	10.4	8.6	11.2	10.0	11.6	18.0	16.9	16.8	8.4	9.2	8.0

% CRUDE FIBRE

Species \ Date	25/9/58	22/10/58	20/11/58	23/12/58	25/1/59	26/2/59	24/3/59	27/4/59	27/5/59	27/6/59	28/7/59
At.	24.8	22.0	21.2	20.0	20.9	22.8	22.5	21.0	28.9	26.0	32.8
Ao.	22.5	22.6	22.9	18.6	19.8	10.6	17.9	17.2	18.6	29.9	47.6
Dc.	30.5	29.8	31.3	29.1	30.0	32.6	28.6	28.0	26.2	34.7	33.3
Df.	29.1	28.1	26.5	20.4	24.5	28.0	27.7	23.0	30.7	36.2	34.1
Fo.	29.0	27.0	26.9	30.3	28.0	27.9	28.0	28.3	30.1	31.0	27.5
Fr.	28.9	28.0	27.0	24.5	26.0	29.2	26.5	24.5	25.1	29.6	39.6
Ho.	24.6	23.0	21.0	18.6	18.7	19.8	20.0	21.0	31.8	27.4	28.1
Ns.	29.3	28.0	27.1	25.7	26.6	31.0	29.8	29.2	33.0	43.6	32.1

Species \ Date	15/8/59	28/9/59	28/10/59	9/11/59	19/12/59	26/1/60	10/2/60	15/3/60	28/4/60	6/5/60	25/6/60	28/7/60	11/8/60
At.	30.0	22.5	18.0	18.4	25.0	27.5	31.3	27.1	25.0	24.0	29.6	30.5	34.6
Ao.	31.2	25.0	28.9	27.6	24.6	21.4	35.7	30.0	25.1	27.6	30.4	30.1	28.6
Dc.	39.0	32.0	33.0	31.5	26.7	31.4	31.6	35.0	21.5	17.9	24.5	24.5	27.0
Df.	23.2	21.7	25.1	24.5	26.2	24.6	32.0	25.2	21.0	18.0	23.6	20.2	21.1
Fo.	27.0	27.9	27.0	26.0	28.0	28.5	30.2	28.4	26.1	29.4	30.7	29.5	33.2
Fr.	38.0	41.6	29.6	28.2	23.5	24.0	25.4	26.2	26.9	24.6	30.0	32.5	30.4
Ho.	32.0	33.0	27.5	23.5	23.0	20.6	20.7	18.1	20.2	21.2	23.2	23.6	27.5
Ns.	34.5	36.2	26.1	22.2	17.8	25.9	29.7	20.7	25.6	36.4	34.6	36.2	31.6

% ASH

Species \ Date	25/9/58	22/10/58	20/11/58	23/12/58	25/1/59	26/2/59	24/3/59	27/4/59	27/5/59	27/6/59	28/7/59
At.	8.3	7.9	7.1	7.0	7.1	7.9	7.2	6.5	6.4	6.0	6.5
Ao.	7.1	5.7	5.9	6.3	6.3	6.9	6.0	5.1	4.6	4.7	6.0
Dc.	5.9	5.9	5.4	6.3	6.0	6.1	6.5	7.0	6.0	4.7	6.4
Df.	6.6	5.0	5.3	6.0	5.2	5.7	5.9	3.0	3.9	6.5	8.5
Fo.	5.8	5.6	5.0	5.6	5.6	5.7	5.5	5.0	4.2	4.7	3.7
Fr.	7.7	7.0	6.4	7.1	7.2	7.1	7.0	6.9	5.5	3.4	5.4
Ho.	10.0	9.1	8.7	9.0	9.2	9.5	9.4	8.9	8.8	5.8	8.4
Ns.	5.7	6.0	6.1	5.9	6.0	6.0	5.4	4.8	5.4	5.4	9.1

Species \ Date	15/8/59	28/9/59	28/10/59	9/11/59	19/12/59	26/1/60	10/2/60	15/3/60	28/4/60	6/5/60	25/6/60	28/7/60	11/8/60
At.	6.5	6.0	5.3	5.8	6.5	6.4	-	7.5	7.4	8.3	8.0	7.9	8.0
Ao.	5.9	-	4.3	4.6	-	5.2	5.3	6.0	6.1	7.0	6.8	6.2	6.3
Dc.	6.3	5.2	4.5	5.1	5.1	4.7	3.9	5.0	5.8	7.6	7.2	6.0	6.1
Df.	4.1	3.6	4.3	4.8	4.7	4.0	2.5	3.1	4.5	5.8	5.8	5.5	5.1
Fo.	3.5	2.4	3.3	4.0	3.5	3.5	3.9	4.5	5.1	4.8	4.9	4.6	4.9
Fr.	5.0	-	4.1	[illegible]	3.9	5.1	7.2	5.2	4.5	4.8	5.4	5.3	4.6
Ho.	8.1	-	7.0	5.2	6.5	8.1	7.7	7.7	7.1	7.3	6.8	6.5	6.2
Ns.	7.5	7.1	6.0	5.8	5.6	5.8	3.9	4.0	5.3	-	6.0	5.8	5.8

% N.F.E.

Species \ Date	25/9/58	22/10/58	20/11/58	23/12/58	25/1/59	26/2/59	24/3/59	27/4/59	27/5/59	27/6/59	28/7/59
At.	53.6	56.8	58.8	58.3	57.5	55.1	53.3	50.5	48.3	54.3	48.4
Ao.	67.0	59.2	59.3	60.2	59.7	58.5	56.9	55.1	54.3	56.1	35.2
Dc.	53.7	54.1	54.5	50.9	50.4	47.3	49.5	47.0	52.8	51.3	50.7
Df.	48.9	51.2	51.6	56.2	53.2	49.0	47.2	59.0	52.3	46.1	42.0
Fo.	52.1	53.9	59.2	51.0	51.9	50.6	50.6	52.4	54.7	53.0	54.6
Fr.	50.4	51.7	52.7	41.9	52.6	59.8	50.6	50.4	54.4	56.7	43.2
Ho.	49.8	51.6	52.6	54.3	53.3	50.7	50.0	46.8	42.4	52.1	49.6
Ns.	53.9	54.9	55.5	56.2	54.6	45.5	46.6	49.4	46.0	40.1	47.8

Species \ Date	15/8/59	28/9/59	28/10/59	9/11/59	19/12/59	26/1/60	10/2/60	15/3/60	28/4/60	6/5/60	25/6/60	28/7/60	11/8/60
At.	52.5	59.7	63.6	61.2	49.1	47.6	-	45.3	46.9	45.2	49.4	48.4	45.0
Ao.	50.8	-	51.2	50.6	-	60.1	42.1	44.9	46.4	44.7	50.8	51.9	53.5
Dc.	55.5	53.1	49.7	59.8	55.8	49.5	50.1	41.9	53.3	51.4	53.4	58.4	55.8
Df.	50.8	61.3	57.7	57.6	50.2	52.9	46.5	50.0	47.4	55.7	56.0	61.8	59.6
Fo.	55.4	57.1	56.7	58.0	57.0	54.5	48.7	49.3	49.8	48.5	52.7	53.7	49.6
Fr.	45.0	-	51.7	-	48.8	47.5	44.3	42.9	40.8	51.5	48.8	49.3	53.5
Ho.	49.6	-	54.2	50.7	47.1	40.6	55.3	46.0	54.8	48.9	51.1	53.3	-
Ns.	47.0	46.4	56.0	62.7	64.3	57.0	46.1	56.3	51.4	-	50.2	47.9	53.6

DEAD HERBAGE

	25/9/58	22/10/58	20/11/58	23/12/58	25/1/59	26/2/59	24/3/59	27/4/59	27/5/59	27/6/59	28/7/59
%NFE	50.2	49.5	51.0	45.1	49.6	49.0	48.8	50.7	50.2	48.2	55.9
%C.P.	6.8	6.3	6.1	10.3	6.1	6.3	6.9	7.0	6.4	6.2	6.0
%C.F.	35.3	37.1	36.7	36.5	36.6	37.3	36.9	35.1	36.4	37.6	31.1
% Ash	6.3	6.1	6.0	6.8	6.6	6.3	6.4	6.2	6.0	6.0	5.9
% Oil	1.4	1.0	1.0	1.3	1.1	1.0	1.0	1.0	1.0	2.0	1.1

	15/8/59	28/9/59	28/10/59	9/11/59	19/12/59	26/1/60	10/2/60	15/3/60	28/4/60	6/5/60	25/6/60	28/7/60	11/8/60
%NFE	51.1	48.7	50.8	49.7	50.6	51.0	47.7	48.5	48.3	49.4	49.4	49.9	50.5
%C.P.	5.9	5.9	6.0	7.0	6.6	6.6	8.7	7.3	6.8	6.5	6.4	6.1	6.3
%C.F.	37.0	37.0	36.2	35.5	35.9	36.0	35.1	36.2	36.7	36.6	36.6	37.0	36.2
% Ash	5.4	6.7	5.8	6.3	5.7	5.4	6.7	6.1	6.2	6.0	6.4	5.8	5.9
% Oil	1.6	1.7	1.2	1.5	1.2	1.0	1.8	1.9	2.0	1.5	1.2	1.2	1.1

Average C.P. 6.9

Average C.F. 35.6

Average Ash 6.1

Average Oil 1.3

APPENDIX 5

Analyses of Pinch Samples (Chapter 5) from four Communities on three Hefts.

AUTUMN 1959 - SPRING 1960

29/10/59

Agrostis/Festuca dominant.

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	8.4	9.9	13.0
	Random	8.4	9.5	10.1
% Ash				
	Selected	7.4	5.7	5.0
	Random	7.2	3.8	5.2
% Fibre				
	Selected	29.2	31.0	27.4
	Random	32.2	29.5	27.3
% Oil				
	Selected	2.4	2.2	2.6
	Random	2.5	1.6	2.6
% N.F.E.				
	Selected	48.5	51.2	52.0
	Random	49.7	55.6	54.8

Pteridium aquilinum dominant.

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	8.5	14.7	10.6
	Random	8.0	12.3	10.1
% Ash				
	Selected	3.4	8.2	6.7
	Random	4.0	6.8	6.8
% Fibre				
	Selected	28.9	25.7	28.6
	Random	29.9	28.8	28.4
% Oil				
	Selected	2.7	2.1	2.5
	Random	2.5	2.0	2.7
% N.F.E.				
	Selected	56.5	49.3	51.6
	Random	55.6	50.1	52.0

Deschampsia flexuosa dominant.

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	9.0	9.0	9.1
	Random	8.9	8.7	8.2
% Ash				
	Selected	5.4	2.4	4.6
	Random	5.5	3.8	5.5
% Crude Fibre				
	Selected	29.1	25.0	23.0
	Random	32.0	30.0	30.0
% Oil				
	Selected	1.7	3.0	2.9
	Random	1.9	1.8	2.3
% N.F.E.				
	Selected	56.5	60.6	60.4
	Random	51.7	55.7	54.0

Nardus stricta dominant.

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	8.1	8.1	8.8
	Random	6.5	5.6	7.2
% Ash	Selected	3.4	7.2	6.9
	Random	6.5	5.0	8.0
% Crude fibre	Selected	31.5	30.6	31.3
	Random	39.5	31.4	35.3
% Oil	Selected	2.7	1.8	2.6
	Random	1.8	2.1	1.6
% N.F.E.	Selected	54.3	52.3	50.4
	Random	45.7	55.9	47.9

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Agrostis/Festuca dominant.

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	8.4	10.3	8.9
	Random	7.2	9.7	8.4
% Ash	Selected	6.7	6.8	4.5
	Random	7.0	5.5	3.2
% Crude fibre	Selected	34.0	32.3	34.5
	Random	34.4	32.6	28.8
% Oil	Selected	2.5	2.4	3.3
	Random	2.3	2.6	1.8
% N.F.E.	Selected	48.4	48.2	48.8
	Random	49.1	49.6	57.8

Pteridium aquilinum dominant.		Gairs	Park Law	Hairney Law
% Crude protein	Selected	10.4	14.3	10.7
	Random	9.5	14.0	10.4
% Ash	Selected	6.8	4.6	5.4
	Random	6.0	4.9	7.0
% Crude fibre	Selected	33.6	29.8	40.5
	Random	33.4	29.5	20.5
% Oil	Selected	2.4	1.7	2.0
	Random	2.2	1.8	2.1
% N.F.E.	Selected	46.8	49.6	41.4
	Random	48.9	49.8	60.0

Deschampsia flexuosa dominant.		Gairs	Park Law	Hairney Law
% Crude protein	Selected	8.9	9.3	9.4
	Random	7.8	8.6	9.1
% Ash	Selected	4.6	2.3	4.6
	Random	4.7	3.8	4.9
% Crude fibre	Selected	28.6	28.6	33.0
	Random	32.2	33.4	20.7
% Oil	Selected	2.9	2.2	3.4
	Random	2.9	3.4	2.8
% N.F.E.	Selected	54.0	57.6	49.6
	Random	52.4	50.8	62.5

Nardus stricta dominant.

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	8.0	8.0	9.3
	Random	6.9	6.9	8.7
% Ash	Selected	5.2	6.9	6.9
	Random	4.5	8.0	3.8
% Crude fibre	Selected	32.0	23.8	20.8
	Random	29.1	35.2	30.6
% Oil	Selected	3.2	2.1	2.1
	Random	2.4	2.0	1.9
% N.F.E.	Selected	51.6	59.2	60.9
	Random	57.1	47.9	55.0

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Agrostis/Festuca dominant.

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	9.7	11.0	10.2
	Random	9.6	9.9	9.9
% Ash	Selected	6.0	4.9	5.3
	Random	5.7	5.2	5.4
% Crude fibre	Selected	41.5	33.0	35.0
	Random	42.0	32.0	40.1
% Oil	Selected	1.8	2.4	2.5
	Random	1.8	2.4	2.3
% N.F.E.	Selected	41.0	48.7	47.0
	Random	40.9	50.5	42.3

<u>*Pteridium aquilinum* dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	10.4	12.7	10.2
	Random	9.8	12.3	9.9
% Ash				
	Selected	3.7	6.8	7.0
	Random	4.2	6.6	6.6
% Fibre				
	Selected	31.0	34.5	30.2
	Random	32.7	36.0	31.6
% Oil				
	Selected	1.5	1.6	2.4
	Random	1.9	1.9	2.4
% N.F.E.				
	Selected	53.4	44.4	49.3
	Random	51.4	43.2	48.9

<u>*Deschampsia flexuosa* dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	10.0	10.1	9.0
	Random	10.0	9.8	8.6
% Ash				
	Selected	2.6	4.1	5.3
	Random	2.9	3.7	5.5
% Crude fibre				
	Selected	34.0	33.4	33.4
	Random	52.5	37.0	35.0
% Oil				
	Selected	2.6	2.3	2.5
	Random	2.6	2.1	2.4
% N.F.E.				
	Selected	50.8	50.1	49.8
	Random	42.0	47.4	48.5

<u>Nardus stricta dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	8.7	7.8	8.5
	Random	6.6	7.5	7.9
% Ash				
	Selected	6.6	6.6	5.9
	Random	5.6	6.4	6.4
% Crude fibre				
	Selected	35.0	36.6	34.6
	Random	37.0	39.9	34.8
% Oil				
	Selected	2.4	1.7	2.3
	Random	2.3	2.0	1.9
% N.F.E.				
	Selected	47.3	47.3	48.7
	Random	48.5	44.2	49.0

<u>1/3/60</u>

<u>Agrostis/Festuca dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	9.8	10.7	10.3
	Random	9.4	9.5	9.4
% Ash				
	Selected	6.1	5.6	5.2
	Random	5.0	5.4	5.8
% Fibre				
	Selected	41.0	32.9	31.5
	Random	36.5	30.9	41.4
% Oil				
	Selected	1.7	2.2	2.2
	Random	1.7	2.2	2.0
% N.F.E.				
	Selected	41.4	48.6	50.8
	Random	47.4	52.0	41.4

<u>Pteridium aquilinum dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	10.3	13.4	10.3
	Random	10.0	12.6	9.4
% Ash	Selected	3.1	7.1	6.8
	Random	5.7	5.7	7.6
% Crude fibre	Selected	31.4	33.5	30.4
	Random	34.6	30.0	30.2
% Oil	Selected	1.4	1.5	1.9
	Random	2.0	2.3	1.8
% N.F.E.	Selected	53.8	44.5	49.4
	Random	47.7	49.4	49.8

<u>Deschampsia flexuosa dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	11.5	10.6	11.5
	Random	9.1	9.6	10.6
% Ash	Selected	2.7	3.9	4.9
	Random	4.7	3.4	5.1
% Crude fibre	Selected	30.0	33.7	32.4
	Random	39.0	36.6	33.4
% Oil	Selected	2.7	2.6	2.2
	Random	2.5	2.5	2.0
% N.F.E.	Selected	53.1	49.2	51.2
	Random	44.7	47.9	50.4

<u>Nardus stricta dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	9.1	7.3	8.7
	Random	7.7	7.7	6.9
% Ash				
	Selected	5.2	6.8	5.7
	Random	4.7	7.9	6.6
% Crude fibre				
	Selected	33.5	36.5	33.7
	Random	34.1	38.9	33.6
% Oil				
	Selected	2.2	1.3	2.4
	Random	2.1	1.9	2.4
% N.F.E.				
	Selected	50.0	51.9	49.5
	Random	51.4	43.6	50.5

<u>4/4/60</u>

<u>Agrostis/Festuca dominant.</u>

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	14.0	16.8	15.0
	Random	12.9	15.0	14.7
% Ash				
	Selected	6.2	5.7	5.7
	Random	5.3	5.3	6.1
% Crude fibre				
	Selected	29.5	24.0	22.0
	Random	34.0	23.5	28.0
% Oil				
	Selected	2.0	2.7	1.9
	Random	2.1	3.0	1.7
% N.F.E.				
	Selected	48.3	50.8	55.4
	Random	45.7	53.2	49.5

Pterididium aquilinum dominant.

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	16.6	19.8	17.7
	Random	14.0	16.9	17.2
% Ash	Selected	4.2	6.9	6.1
	Random	4.0	5.9	5.2
% Crude fibre	Selected	26.9	22.0	23.1
	Random	27.8	23.6	25.6
% Oil	Selected	1.9	2.0	2.0
	Random	2.5	1.9	2.2
% N.F.E.	Selected	50.4	49.3	51.1
	Random	51.7	51.7	49.8

Deschampsia flexuosa dominant.

		Gairs	Park Law	Hairney Law
% Crude protein	Selected	15.5	12.2	13.2
	Random	14.0	12.4	11.1
% Ash	Selected	3.5	3.8	5.0
	Random	3.1	3.2	4.7
% Crude fibre	Selected	26.1	28.7	27.6
	Random	28.0	27.7	30.1
% Oil	Selected	2.6	2.6	2.5
	Random	2.3	2.4	2.5
% N.F.E.	Selected	52.3	53.3	51.7
	Random	52.6	54.3	51.6

Nardus stricta dominant.

		Gairs	Park Law	Hairney Law
% Crude protein				
	Selected	14.0	12.4	13.0
	Random	13.3	11.3	9.0
% Ash				
	Selected	5.4	5.1	5.6
	Random	5.1	4.3	6.0
% Crude fibre				
	Selected	30.0	30.4	30.1
	Random	32.2	31.6	32.2
% Oil				
	Selected	2.4	1.7	2.6
	Random	2.2	1.6	2.4
% N.F.E.				
	Selected	48.2	50.4	48.7
	Random	47.2	51.2	50.4

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Agrostis/Festuca dominant.

		Gairs	Fassett	Hairney Law	Park Law
% Crude protein					
	Selected	13.1	11.8	10.8	8.9
	Random	11.5	11.4	8.2	6.8
% Ash					
	Selected	6.0	6.5	5.6	6.4
	Random	6.1	6.9	6.2	6.6
% Crude fibre					
	Selected	28.3	28.2	30.6	28.2
	Random	28.8	33.7	31.5	32.8
% Oil					
	Selected	2.4	2.4	2.4	2.4
	Random	2.4	2.5	2.4	2.4
% N.F.E.					
	Selected	50.2	51.1	50.6	54.1
	Random	51.2	45.5	51.7	51.4

2/4/59

Agrostis/Festuca dominant.

		Gairs	Fassett	Hairney Law	Park Law
% Crude protein					
	Selected	16.3	16.6	16.2	18.5
	Random	15.1	15.0	12.7	17.0
% Ash					
	Selected	6.2	6.8	7.8	6.7
	Random	6.1	6.6	4.9	6.7
% Crude fibre					
	Selected	27.5	21.1	23.5	23.9
	Random	27.5	26.2	29.4	25.3
% Oil					
	Selected	2.3	2.7	1.9	2.4
	Random	1.8	2.3	1.7	2.2
% N.F.E.					
	Selected	47.7	47.8	50.6	48.5
	Random	49.5	49.9	51.3	48.8

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Bracken		Gairs	Fassett	Hairney Law	Park Law
% Crude protein					
	Selected	12.9	14.7	11.9	19.4
	Random	11.3	11.4	10.8	16.9
% Ash					
	Selected	6.5	6.2	6.9	7.4
	Random	6.6	6.2	6.6	7.6
% Crude fibre					
	Selected	29.6	28.4	30.3	27.9
	Random	31.2	29.2	30.8	28.4
% Oil					
	Selected	2.5	2.4	2.4	2.5
	Random	2.4	2.4	2.4	2.4
% N.F.E.					
	Selected	48.5	48.3	48.5	49.8
	Random	47.5	50.8	49.4	44.7

2/4/59

Bracken		Gairs	Fassett	Hairney Law	Park Law
% Crude protein	Selected	16.7	20.1	17.1	23.4
	Random	13.9	16.2	13.2	18.4
% Ash	Selected	7.2	6.8	7.1	8.3
	Random	5.5	6.1	5.9	7.5
% Crude fibre	Selected	27.2	25.7	25.5	21.1
	Random	28.2	27.5	31.1	25.1
% Oil	Selected	2.3	2.2	1.6	3.1
	Random	1.7	1.7	1.3	2.7
% N.F.E.	Selected	46.6	45.2	48.7	49.1
	Random	50.7	48.5	48.5	46.3

3/3/59

Deschampsia flexuosa		Gairs	Fassett	Hairney Law	Park Law
% Crude protein	Selected	8.6	11.9	15.0	14.1
	Random	10.2	10.1	10.4	10.2
% Ash	Selected	6.5	5.4	5.7	6.0
	Random	6.9	6.2	5.9	4.5
% Crude fibre	Selected	29.9	29.3	32.2	30.6
	Random	32.0	30.6	29.6	33.3
% Oil	Selected	2.4	2.4	2.4	2.5
	Random	2.5	2.4	2.5	2.4
% N.F.EL	Selected	52.6	51.0	44.6	47.4
	Random	48.4	50.7	51.7	49.7

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Deschampsia flexuosa		Gairs	Fassett	Hairney Law	Park Law
% Crude protein					
	Selected	16.3	16.6	13.9	11.8
	Random	14.0	13.6	11.4	9.5
% Ash					
	Selected	5.5	6.2	5.7	5.2
	Random	6.2	6.5	6.3	4.8
% Crude fibre					
	Selected	26.3	26.1	28.3	30.0
	Random	26.9	27.6	31.3	31.4
% Oil					
	Selected	2.4	2.7	2.1	2.5
	Random	2.6	2.2	1.4	2.4
% N.F.E.					
	Selected	49.5	48.4	50.0	50.5
	Random	50.3	50.1	49.6	51.9

APPENDIX 6.

Part 1

An attempt to assess the amount of dead material consumed by hill sheep in winter.

Introduction

In view of the difficulties involved in the visual estimation of the quantity of dead material consumed by sheep, an attempt was made to develop an objective rather than a subjective method.

The most suitable method appeared to be the use of a naturally occurring indicator or reference substance, the presence of which is proportional to the amount of dead (or green) material, which is indigestible and is recoverable in the faeces.

This method is discussed here and not in the main body of the thesis since the method did not prove very satisfactory and without a great deal more accuracy would not yield useful information

Review of Literature.

Reid et al. (1950), Ellis, Matrone and Maynard (1946) have discussed the use of lignin as an indigestible indicator for digestibility determinations. Blaxter (1948) has also developed a double indicator technique using lignin as the naturally occurring reference substance. As the lignin content per unit dry weight is very much higher in dead material than in green the possibility exists of using this to establish a relationship between faecal lignin and the quantity of dead material ingested.

Woehlbier (1939) and Reid J.T. et al. (1950) consider the possibility of using chlorophyll or a complex mixture of all the plant pigments as a digestibility reference substance. Reid et al. report a simple technique employing the chromogens absorbing light at 406 mμ.

Although Cook and Harris (1951) and Davidson (1954) have cast serious doubts on the existence of a single chromogenic substance absorbing light at 406 mμ and show innaccuracies in digestibility determinations of 3 - 7%, the chromogen method could provide an easy method of roughly determining the quantity of dead material ingested by sheep.

Method

In view of the ease of measurement of faecal pigmentation this was the method finally chosen.

The investigation was divided into two parts, an initial feeding experiment using dried grass in winter, and a second feeding experiment in early spring. The range of the initial feeding experiment was from 0% - 100% of dead and the range of the second was from 45% - 80%. The pigmentation of the dung was measured in a standard way in each experiment, and complete extraction was not attempted.

The dung from each animal was collected at 9.00 hours and 17.00 hours before drying in a standard laboratory oven at 100°C. The dung pellets were broken down before drying, in order to ensure uniform temperatures at the centre of each dung pellet.

When dry, the dung was ground using a pestle and mortar, sub sampled and one gram accurately weighed into a 25 ml. beaker. Twenty ml. of methyl alcohol were then added to extract the fat soluble pigments. Extraction was continued for exactly 7 minutes and the mixture stirred twice and filtered. Five ml. of the filtrate was diluted with its own volume of methyl alcohol and the colour density compared with pure methyl alcohol in an Eel absorbtiometer using the 5 mm. cell and number 601 filter (42-44mμ) obtaining maximum deflection. In the second experiment, however, five ml. were diluted with 10. ml. methyl alcohol to bring the values within the scale.

Intial experiment.

This was carried out using grassmeal cubes obtained in the normal way from suppliers and extracted grass meal cubes obtained from British Crop Driers Ltd. These cubes consisted of dried grass from which the majority of pigments had been extracted and to which a small quantity of straw meal had been added. The four rations fed were:

1. Normal dried grass 100%
2. Normal dried grass 75%
   Extracted grass meal 25%
3. Normal dried grass 50%
   Extracted grass meal 50%
4. Extracted grass meal 100%

These rations were fed at the rate of 4 pounds per day split into two portions. This amount was eaten fairly readily by most of the ewes, thereby reducing the chances of selection. The ewes which were in lamb increased slightly in weight. Although the ewes were bedded on sawdust to facilitate dung collection, they attempted to chew the bedding and the wooden posts of the pen. This was prevented by substituting oat straw and/or whole dried grass for part of the diet.

The experimental design was a double Latin square made up as below:

	Period 1	2	3	4
Animal 1,5	A	B	C	D
2,6	B	D	A	C
3,7	C	A	D	B
4,8	D	C	B	A

Two animals were alloted at random to each sequence and the diets were alloted at random to the letters. In order to prevent any possible residual effects four complete days were allowed on each diet before sampling the dung morning and evening.

Results.

The results given in Table 31 show the % light absorbtion at the four levels considered, using the Eel absorbtiometer filter 601.

TABLE 31

The dung extract solution density at various levels of green dry matter content.

Sheep number.	100% green matter	75% green matter	50% green matter	0% green matter.
1	90	54	27	8
5	92	58	35	12
2	92	66	25	7
6	98	74	33	12
3	95	36	34	12
7	83	52	26	10
4	96	64	33	12
8	100	75	38	10
Mean	93.2	59.8	31.8	10.3

The mean figure for solution density is plotted against % green material in Diagram 17 page 191 with a probable curve drawn in.

A relationship appears to exist therefore between the pigmentation of the diet and the pigmentation of the dung and hence the pigmentation of the dung may be used to elucidate the quantity of green (or dead) material consumed by the sheep.

Second Experiment.

It was realised that the preliminary experiment was unsatisfactory for two reasons. The dried and extracted dried grass were not comparable with green and dried grass available on the hill. This, together with the low number of diets considered, gave little opportunity for establishing a true relationship between dung pigmentation and diet.

The second experiment initially involved eight sheep and tested eight levels of dead material in the diet. Owing to the refusal by one sheep to eat anything when penned, seven diets and seven sheep were finally used.

The diets were made up using dead herbage collected and dried in winter and fresh herbage cut in the spring during the feeding trial. The fresh material contained very little dead material, but a sample of it was separated into dead and green components each day and the quantity added to the diet modified if necessary. The dry matter was also determined in order to calculate the proportions required. All seven sheep were fed on the same diet during each period to reduce labour and four clear days were allowed between sampling. In order to reduce selection the herbage was chopped in a conventional chaff cutter.

Great difficulty was experienced in reducing the variability between sheep. Two reasons for this are suggested, the presence of a diurnal fluctuation in the excretion of pigment (in this investigation the afternoon samples were invariably higher in pigmentation) and, in the higher dead material diets, an unwillingness to consume the diet.

In spite of the difficulties and variabilities encountered it was considered useful to record them. The results are given in Table 32 and the graph of solution density against % green is given in Diagram 18. Dung was collected morning and evening for two days and averaged.

TABLE 32

Solution density (dung extract) at various levels of green matter content (on a dry matter basis).

Evening collection

	% Green material						
Sheep No.	55%	50%	40%	35%	30%	25%	20%
1	28	29	27	25	24	23	21
2	28.5	28	30	24.5	25	24	20
3	30	28	25	19	21	21	17
4	29	27	30	25	21	24	18
5	28	28	26	24	23	21	20
6	28.5	28	27	25	24.5	24	20
7	43.5	35.5	31	27	27.5	24.5	34.5
8	30.5	29	24	17.5	22.5	21.5	16.5
Mean	30.7	29	27.5	22.3	23.5	22.0	20

TABLE 32 (Continued)

Morning Collection.

Sheep No.	55%	50%	40%	35%	30%	25%	20%
1	26	26	32	26	14.5	16	20
2	29	27.5	28	22	20.5	21	19
3	27	28.5	20	22.5	18.5	20.5	17
4	32	28	28	27	18	19	17.5
5	27	26	26.5	25	19	17	16
6	26	26	27	22.5	14.5	16	20
7	27	28.5	26	24.5	18.5	20.5	17
8	28.5	28	34	20	25	24	20
Mean	27.5	27.3	27.5	24.3	28.5	19	18.2

(% Green Material)

Mean of morning and evening.

55	50	40	35	30	25	20
29.2	28.1	27.5	23.8	21	20.5	19.1

Diagram I7

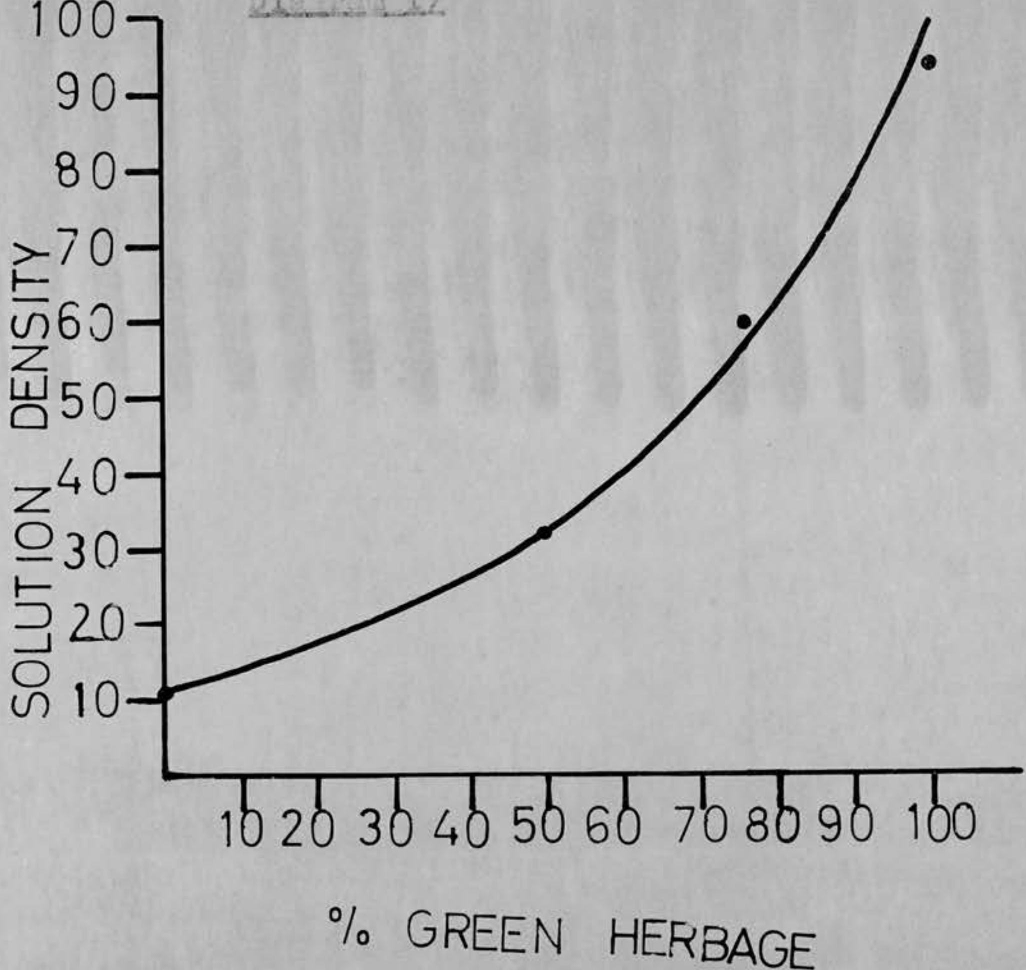


Diagram I8

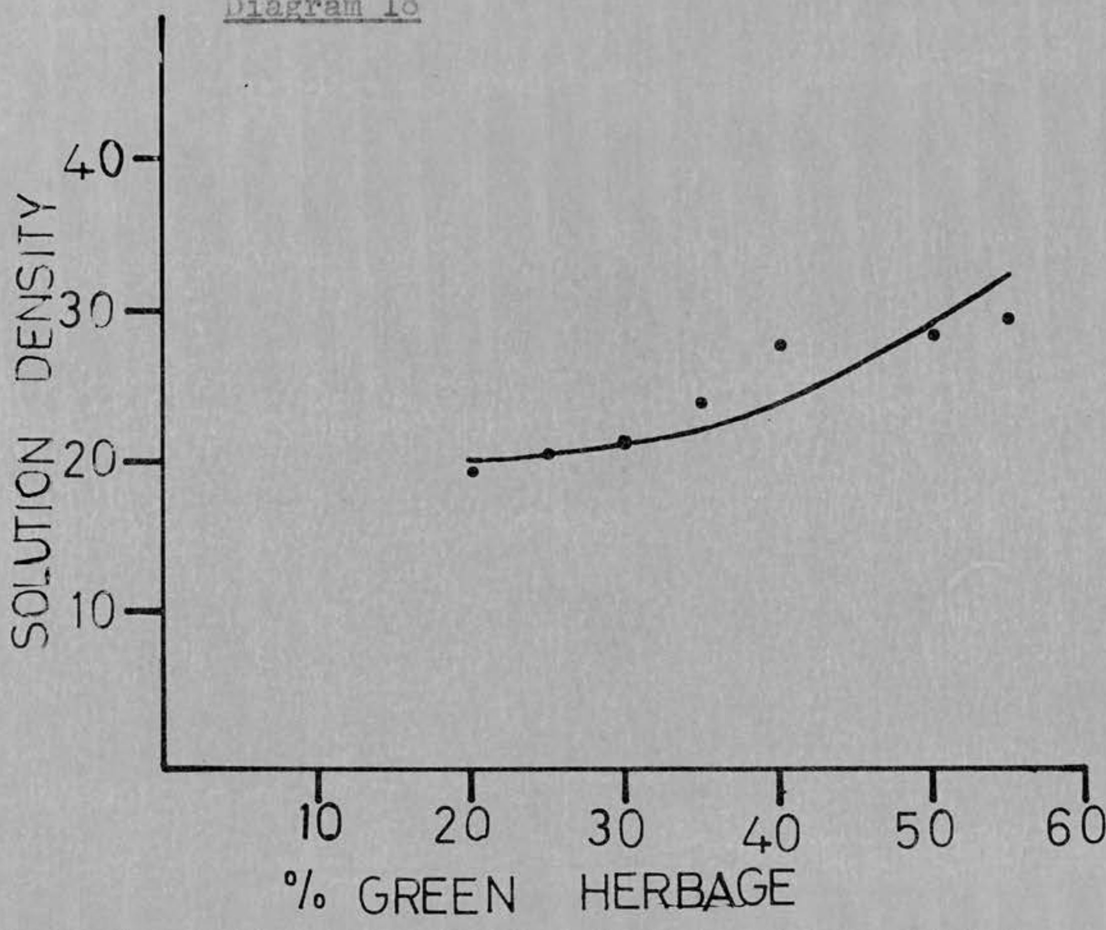
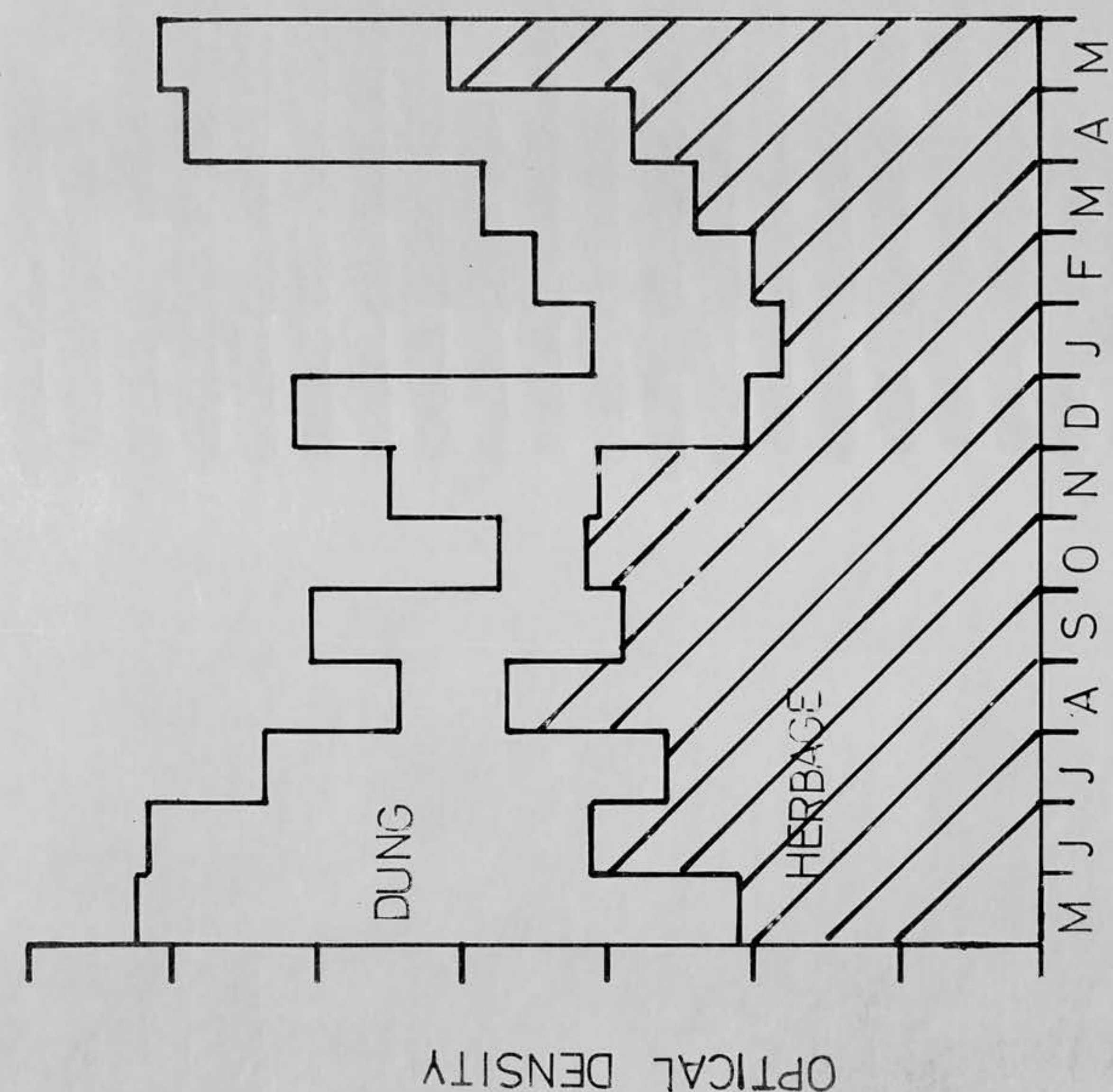


Diagram I9



Conclusions.

Although the investigations reported above are not conclusive and are only of an exploratory nature, they open up interesting prospects.

It appears that there is a relationship in sheep between the pigmentation of the dung and that of the diet. This relationship can be extended to an estimation of the qualitative composition of the diet as it has been shown in Chapter 3 that the composition of dead herbage is constant and much lower in feeding value than green herbage.

Further work on this relationship should provide a method of determining the quality of the hill sheep's diet. In the absence of reliable digestibility and intake data this would provide some standard for determining the level of supplementary feeding required by hill ewes in winter.

Part 2

Seasonal fluctuation in the pigmentation of the dung of hill sheep and an attempt to establish a connection between dung pigmentation and territory.

Introduction.

In view of the difficulty experienced in establishing an accurate relationship between dung pigmentation and the quality of the food intake no attempt was made to apply the method directly to determining the qualitative composition of the diet.

It was considered useful, however, to investigate two aspects of the sheep/pasture relationship by means of the technique. It is likely that the quantity of dead material ingested by the animal will vary in two ways, seasonally and territorially. The increase in dead material in winter will cause the sheep to increase its intake of dead material involuntarily and this should be reflected in a lower level of dung pigmentation. Any change in herbage digestibility in winter will tend to complicate this but it is hoped that gross differences will be apparent. The change in pigmentation of the available herbage was measured to provide an indication of this. The amount of dead material ingested should also vary with the communities grazed and hence with territory. A measure was, therefore, made of dung pigmentation from groups of ewes grazing territories to investigate the validity of the assumption.

Methods.

Seasonal fluctuation

The Hairney Law heft was used for this investigation. Throughout one year from May 1959 - May 1960 the dung from eight sheep was collected and individually examined in the Eel absorbtiometer. Collections were made monthly in the mornings; sheep being followed until defaecation took place. There was no way of identifying the individual sheep on subsequent occasions. Drying of the faeces and extraction of pigments were carried out as described on page185 but 5 ml. of the filtrate were diluted with 15 ml. of methyl alcohol to bring the readings on to the Eel scale.

To obtain a herbage sample for analysis ten six-inch quadrats were cut on three sites (Pteridium, Deschampsia flexiosa, and Agrostis/Festuca dominant) and the herbage mixed, halved anddried at 85°C before grinding. Pigments were extracted in a similar manner to the dung and 5 ml. of the filtrate diluted with 15 ml. methyl alcohol.

Territorial differences.

Twenty grams of dung of the selected sheep grazing the Gairs heft was collected at dawn as the sheep were leaving their resting place. It proved very easy to obtain the requisite samples as the ewes invariably defaecated as they moved off. The dung was dried and ground and extracted with methyl alcohol, as previously described. No significant differences were detected when the colour density at Filter 601 was determined.

A more exact method was therefore used involving the determination of the optical density at 415mμ in a spectrophotometer using 85% acetone as a blank. One gram. of the faeces was extracted with 80 ml. 85% aqueous acetone for 15 minutes using an M.S.E. homogeniser running at half speed. The sample was filtered by suction and washed three times with 50ml. portions of acetone. The extract was then suitably diluted to give an optical density of 0.3 to 0.4 at 415mμ.

Results.

The results of the seasonal fluctuation investigation are given in Table 33. A histogram showing the dung and herbage pigmentation at monthly intervals is shown in Diagram I9.

The optical density at 415mμ of twenty samples from two areas on the Gairs and Dod are given in Table 34.

TABLE 33

Solution density of extracts of dung and herbage at monthly intervals over the year measured with filter No. 601 Eel absorbtiometer.

Date	Dung Solution Density (601 filter) Mean of 8 sheep.	Herbage Solution density (601 filter)
9/5/59	62.7	21
15/6/59	61.7	31
30/7/59	53.7	26
31/8/59	44.6	37
18/9/59	50.3	29
19/10/59	37	31.5
14/11/59	45	31
9/12/59	51.6	20.5
7/1/60	31.2	18
1/2/60	35	20
14/3/60	38.8	24
14/4/60	59.3	28.5
12/5/60	60.8	41

TABLE 34

Optical density at 415mμ of extract from 1 gm. of faeces taken from two groups of ewes grazing separate territories.

Gairs Group		Dod Group	
306	0.366	238	0.562
573	0.321	897	0.518
857	0.321	847	0.541
838	0.435	115	0.475
585	0.359	845	0.488
644	0.485	833	0.530
858	0.626	*	0.506
543	0.465	*	0.580
896	0.528	*	0.551
856	0.495	*	0.629
Mean	0.538		0.440

* These were ewes which rested on the Dod and grazed with the Dod group of sheep at least on the collection date. It can be safely assumed that they are part of the normal population of the Dod.

There is a significant difference between the means at the 0.05 level.

Discussion and conclusions.

Although the relationship between dung pigmentation and diet quality is not accurate enough to detect small differences it is able to detect gross diet differences. Such differences obviously occur from month to month and are shown in Diagram 19.

Diagram 19 shows several interesting points regarding the winter diet of the ewe. It can be seen that dung pigmentation and herbage pigmentation do not have the same pattern in the early part of the experimental period although subsequently there is broad agreement between the two. There are two discrepancies: a secondary peak in dung pigmentation in November, December and a steeper rise in March and April. It is possible that the peak in November and December is caused by the movement of sheep on to the bracken areas although normally this would occur at an earlier date. The steep rise in spring is a reflection of the greater opportunity for selection at this time, permitting the inclusion in the diet of a higher percentage of green herbage.

The pattern of dung pigmentation is therefore:-

1. A peak in April, May, June.
2. A relatively slow decline from July to January complicated by secondary peaks and troughs.
3. A slow increase in February and March.
4. A steep rise in April.

Since it is suggested that dung pigmentation is related directly to diet quality the above pattern enables some estimation of the quality of the diet and hence the type of supplement required.

Although sheep can select a high green-matter diet from relatively low green-matter herbage their actual intake of green herbage must be influenced to a very large extent by the amount available. This implies that the intake of green is influenced by the community grazed, since different communities possess differing quantities of dead. It has been shown that this is the case and the difference in optical density at 415mμ must indicate a difference in either intake or digestibility of the herbage and must, therefore, result in the ewe obtaining lower diet levels on certain communities. This emphasises the important differences which territoriality and home range can make to the diet of the individual ewe and families of ewes.

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